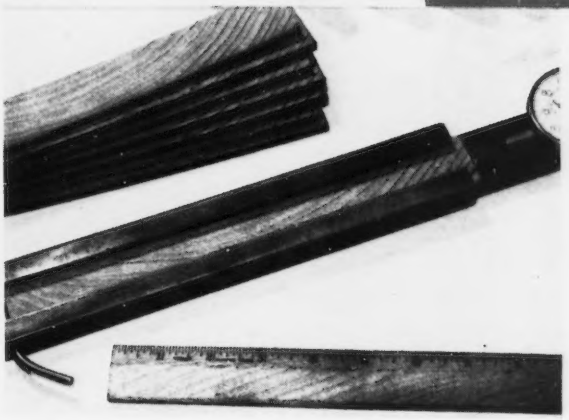
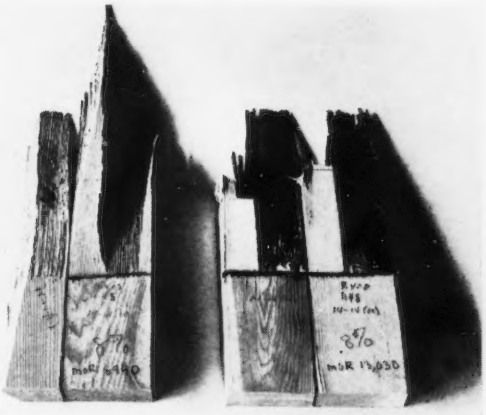
FOREST PRODUCTS JOURNAL

FOREST PRODUCTS RESEARCH SOCIETY

Water sprays prevent stain and decay, p. 277



Dimensional stability with aldehydes, p. 306



Tests of finger joints at high MC, p. 287

Cost analysis of wood chips as cargo, p. 282

1960/JUNE

HERE'S A WATER TIGHT STORY

— Plywood bonded by waterproof Melurac® 305 resin adhesive! Get waterproof bonds with any wood—surpassing FHA, Commercial Standard (CS 35-56) and the toughest Military Specifications. Melurac 305, a melamine-urea adhesive, readily takes the double cycle four-hour boil. You get superior results **at no increase in price.** It's non-staining, long-working, easy to handle and cures at moderate temperatures. Use it for block flooring, veneered doors and exterior and marine grade plywoods.

AMERICAN CYANAMID COMPANY · PLASTICS AND RESINS DIVISION
30 Rockefeller Plaza, CYANAMID New York 20, New York

Offices in: Boston · Charlotte · Chicago · Cincinnati · Cleveland · Dallas · Detroit · Los Angeles · Minneapolis · New York
Oakland · Philadelphia · St. Louis · Seattle · In Canada: Cyanamid of Canada Limited, Montreal and Toronto

FOREST PRODUCTS JOURNAL

Vol. X, No. 6 June, 1960

CONTENTS

PRESERVATION Page

Water Sprays Protect Hardwood Logs from Stain and Decay ..... *P. H. Lane and T. C. Scheffer* 277
Winter-cut birch and maple logs deck-stored under water sprays were free of decay while unsprayed logs had 7 to 10 inches of rot.

UTILIZATION

Transporting Wood Chips by Truck ..... *H. E. Lovejoy* 282
Economic transport is a key item in the profitable utilization of wood residues.

Lumber Mill Integration from Woods to Car Door ..... *N. T. Shelton* 301
The case history of a forest products center.

DIMENSIONAL STABILITY

Dimensional Stabilization of Wood With Aldehydes and Related Compounds ..... *J. W. Weaver, J. F. Nielson, and I. S. Goldstein* 306
Tests to determine whether aldehydes would act as cross-linking reagents with cellulose in whole wood produced negative results.

GLUES AND GLUING

Finger Jointing at High Moisture Content ..... *R. A. Currier* 287
An evaluation of the effect of drying stresses on end-glued studs.

Effect of Wettability of Wood on Glue-Line Behavior of Two Urea Resins ..... *H. G. Freeman and F. F. Wangaard* 311
The inter-relationships between assembly time, glue-line solids and viscosity, and glue-joint strength.

VENEER AND PLYWOOD

The Potential of Western Hardwoods for Veneer and Plywood .. *P. H. Koehler* 294
Estimates show 23 billion feet of merchantable logs on the Pacific Coast.

Techniques for the Development of a Rational Grading System for Hardwood Veneer Logs ..... *J. S. Bethel and C. A. Hart* 296
Procedures for collecting and analyzing data for use in the development of grades for hardwood veneer logs.

INDUSTRY–EDUCATION

The Lumber Industry's Stake in Education ..... *R. H. Gloss* 303
Each segment of the industry must invest in an educational effort in behalf of better products and consumer promotion.

PROPERTIES

Some Mechanical Properties of Wood Fibers in Tension ..... *B. A. Jayne* 316
Measurements of load-deformation properties of single fibers of wood.

Diffusion Through Air-Filled Capillaries of Softwoods—Part II: Water Vapor ..... *Harold Tarkow and A. J. Stamm* 323
Part of a series of reports of fundamental studies on moisture movement in wood.

DEPARTMENTS

News Digest 5-A
Employment Opportunities 11-A
Abstracting the Literature 325
World Wide Forest Products News 328
"Briefing" FPRS Papers 293

Editor
John K. McDonald, Madison, Wis.
International Editor
R. W. Wellwood
President
R. H. Berry, Burney, Calif.
President-Elect
D. K. Saunders, Westbrook, Maine
Vice President
T. S. Veazey, Bonner, Montana
Past President
E. S. Harrar, Durham, N. C.
Executive Secretary
Frank J. Rovsek, Madison, Wis.

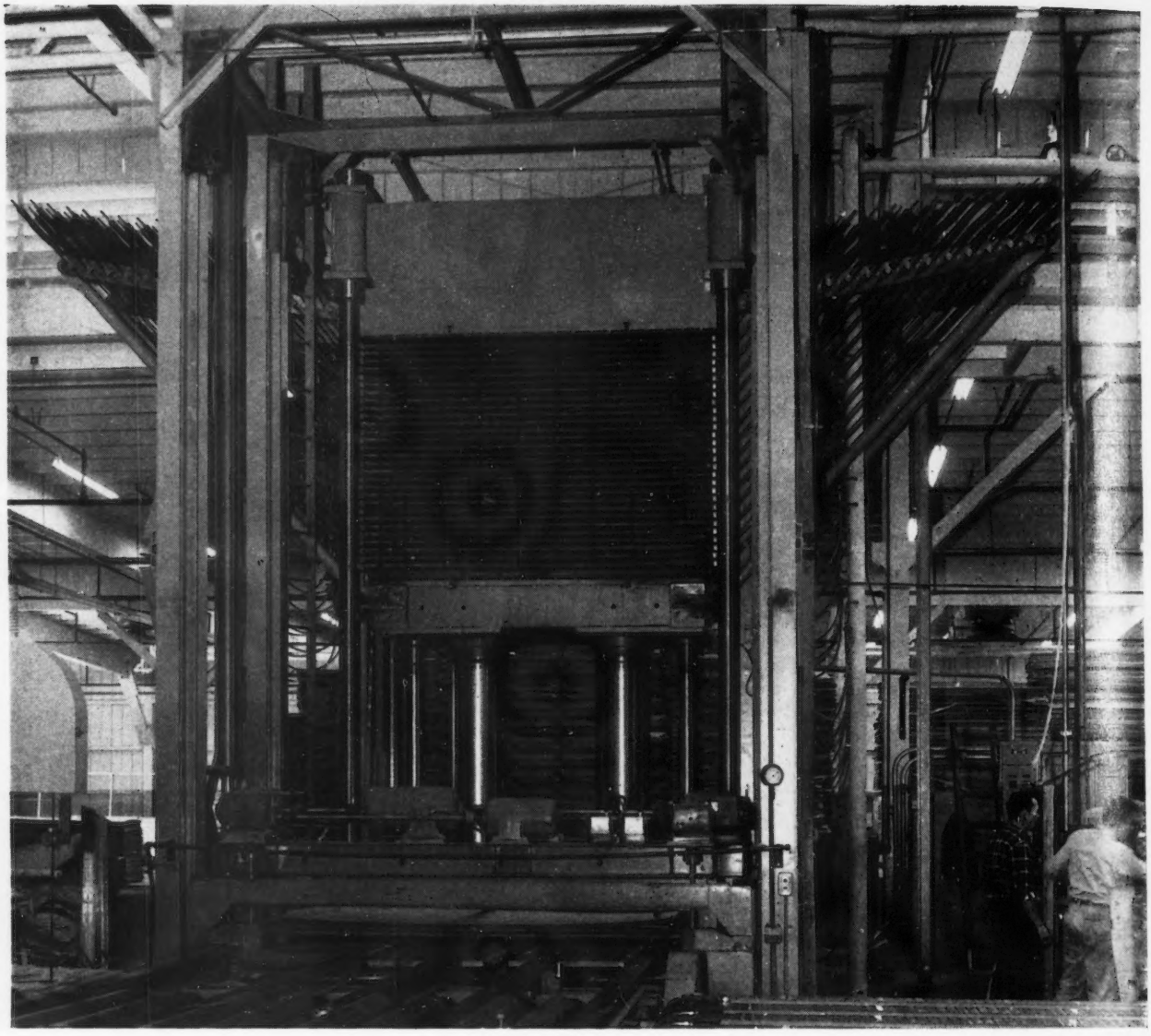
THE FOREST PRODUCTS JOURNAL is published monthly by the Forest Products Research Society, 417 North Walnut Street, Madison 5, Wisconsin. Second-class postage paid at Madison, Wisconsin.

Annual subscription rate, $15.00; single copies $1.00, except October Yearbook Number, $4.00. Annual subscription rate is $11.25 with voting, associate, and supporting memberships in the Society. Remittances should be made payable to the Forest Products Research Society.

Correspondence on editorial matters should be addressed to the Editor, at the Executive Office. The Society is not responsible for views expressed in publications.

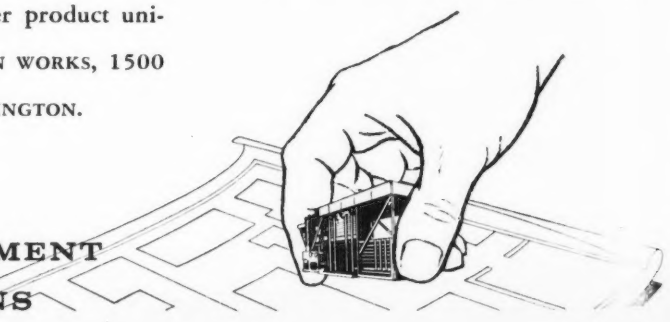
Time has brought decisive progress in the fight against cancer. Ten years ago one in four persons with cancer was saved. Today it's one in three. But time alone will not conquer cancer. Time plus research will. And research needs your dollars. Send your contribution today to "Cancer," c/o your local post office.

AMERICAN CANCER SOCIETY



A 30-opening counterbalanced hot press?

There are few 30-opening presses and we know of only two (both designed and built by us) with a simultaneous-closing feature. For laminates or board products from bagasse, flakes, chips or fibers—the advantages of the counterbalance feature are the same: faster closing (more than three times faster), no "blow" and always uniform pressures on all platens. Counterbalanced multi-platen hot presses up to thirty openings can make a big difference in your plans. Our experience can give you higher production with greater product uniformity. Write or call WASHINGTON IRON WORKS, 1500 SIXTH AVENUE SOUTH, SEATTLE 4, WASHINGTON.



WASHINGTON PRESS EQUIPMENT HAS A PLACE IN YOUR PLANS

Let National Casein help you PROLONG THE LIFE OF YOUR WOOD PRODUCTS

Woodtrol (WRP)

water repellent preservative protects wood from destructive insects, rot and stain . . . imparts water repellency to wood.

Woodtrol (WRL)

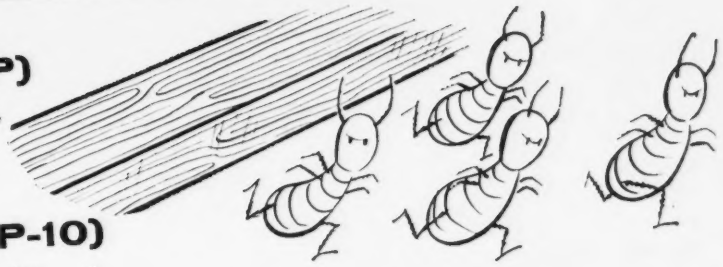
water repellent lubricant reduces friction between moving wood parts and makes wood water repellent.

Woodtrol (P)

preservative for millwork, furniture and structural lumber.

Woodtrol (P-10)

Woodtrol (P) concentrate for large quantity users.



"That lumber's too highly seasoned for us!"

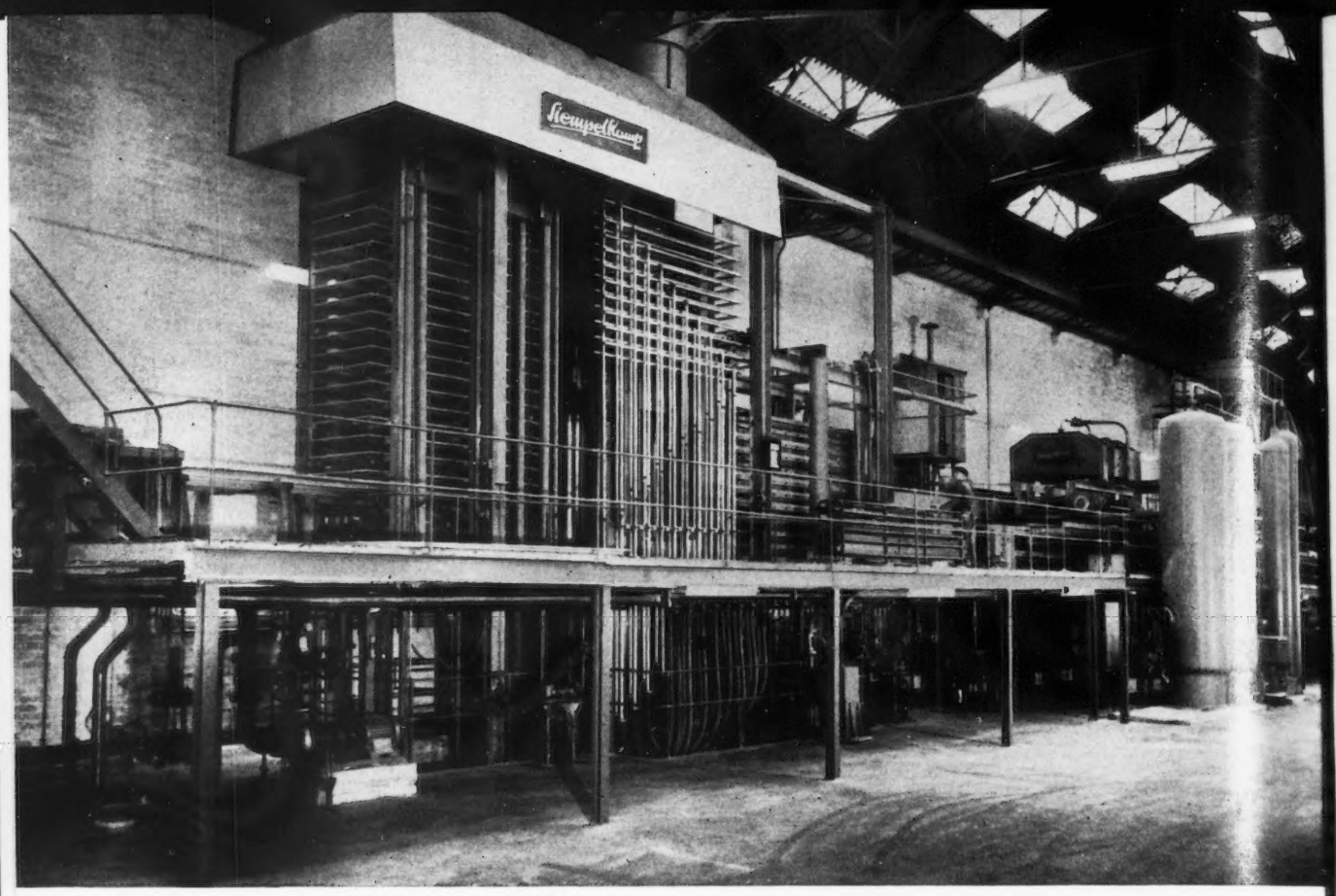
YOUR "NATIONAL CASEIN" GLUE MAN HAS NEWS FOR YOU

In addition to helping you determine the right glue for your job—the "National Casein" man who calls on you is now equipped to help you protect your wood products against deterioration from mechanical wear, moisture, mildew, rot, stain and from insects. "National Casein's" Woodtrol series of wood protectors is helping the furniture, millwork and structural lumber industries to prolong the life, beauty and usefulness of their wood products and wood construction. Write for data, prices, samples. Ask the "National Casein" man who calls on you about Woodtrol wood protection, or contact the office nearest you. No obligation to purchase.

National Casein

National Casein Company, 601 W. 80th Street, Chicago 20, Illinois and Tyler, Texas

National Casein of New Jersey, Broad & Fulton Streets, Riverton, New Jersey



Automatic press plant of Messrs. Linex - Belgium

Chip Board and Particle Board Press installation

suitable for:

- All Types of applicable raw materials
- All Manufacturing processes
- All Stages of automation
- All required capacities

Siempelkamp

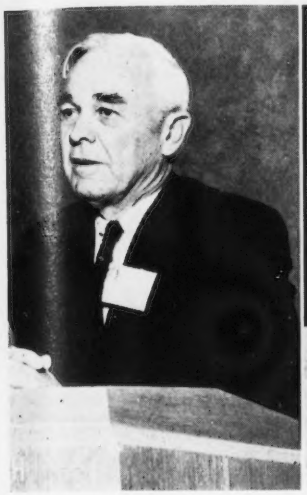
G. Siempelkamp & Co. · Maschinenfabrik · Krefeld

Telegramme: siempelcampco, Krefeld · Telefon: 28251 · Telex: 085381

1960 National Meeting Papers in This Issue on Pages 277 & 311

FPRS News-Digest

International Meet At Montreal Attracts 586 Registrants



Dr. A. J. Stamm, Associate Research Professor, North Carolina State College, presented the FPRS " Honorarium Lecture," sponsored by the Midwest Section.

The Honorable Lionel Chevrier presented a dynamic and extremely well received Official Luncheon Address on the economic advantages of the St. Lawrence Seaway.

R. H. Berry (left) and Dr. E. S. Harrar (right) greet Mayor Sarto Fournier, as he extended a cordial and most gracious welcome to the lovely City of Montreal.

The Forest Products Research Society's 14th Annual Meeting, and the first held in an International setting, drew 446 men and 140 ladies to hospitable Montreal, Canada, June 5 through 9. Although primarily from the United States and Canada, the group also included representatives of Australia, Germany, Finland, New Zealand, Belgium and Japan.

The week was marked by spirited activity, not only at the 19 technical sessions at which 67 papers or panel discussions were presented, but also at the various business meetings conducted to review and revise the Society's internal affairs.

Following are a few of the highlights of some of the more important business conducted; a complete report of the meeting will be published in the October Yearbook issue.

New Officers

The report of the Tellers Committee, presented by Chairman Robert DeGrace at the Annual Business Meeting, announced the election of the following executive officers and board members: President—R. H. Berry, Vice-president and General Manager, Scott Lumber Co., Inc., Burney, Calif.; President-Elect—D. K. Saunders, President Saunders Brothers, Westbrook, Maine; Vice-President—T. S. Veazey, Forest Products Engineer, Anaconda Co; Lumber Dept.; Bonner, Montana; Past-President—Dr. E. S. Harrar, Dean, School of Forestry, Duke University, Durham, N. C.; Northeast Regional Board Member—Dr. E. A. Anderson, Chairman, Department of Wood Technology, State University of New York, Syracuse, N. Y.; Northwest Regional Board Member—R. J. Seidl, Director of Research, Simpson Logging Co., Seattle, Wash.; North Central Region Board Member—A. F. Muschler, Engineering and Development Division, Edward Hines Lumber Co., Chicago, Ill., appointed to a one-year term after resignation of J. J. Allegretti.

Executive Secretary Resigns

Dr. E. S. "Scotty" Harrar regretfully announced the resignation of Executive Secretary Frank J. Rovsek and thanked him for his 10 years of "sincere and dedicated efforts on behalf of the Forest Products Research Society."

Constitution Changes

An Executive Board recommendation to raise the Voting and Associate dues in 1961 to $20.00 was presented at the Annual Business Meeting by J. J. Allegretti, Chairman of the Constitution and By-Laws Committee. A majority of the voting members present approved the action, intended to raise the society's operating revenue and improve its services, and the amendment will now be submitted to the membership at large for ratification by mail ballot. Upon ratification, new members will be accepted currently at the new rate, present members will be invoiced at $20.00 beginning Jan. 1, 1961.

Mr. Allegretti also presented a proposal to incorporate the Divisions into the Constitution thereby giving them legal status on par with Sections. This proposal will also be submitted to the general membership by mail ballot.

Division Organization

Division Coordinator, D. K. Saunders, presented a proposal for a reorganization of the 14 Subject Matter Division into 11 Divisions designated by generic titles and broken down into various products subdivisions. The following divisions were recommended.

Division 1: Anatomy and Fundamental Properties
Division 2: Timber Production
Division 3: Mechanical Conversion
Division 4: Chemical Conversion
Division 5: Particle and Fiber Processes
Division 6: Glues and Gluing Processes
Division 7: Treatments and Coatings
Division 8: Drying
Division 9: Engineering
Division 10: Production Management
Division 11: Marketing

The new division organization was approved by the Executive Board and the various Division Chairmen.

1961 National Meeting

The 15th National Meeting of the Forest Products Research Society will be held June 16–22, in Louisville, Kentucky, with Carl Trinkle, Baldwin Piano Co., Cincinnatti, Ohio, serving as General Chairman.

Ernest C. Betts, Jr., Director of Personnel, U.S.D.A., presents the Distinguished Service Award, the Department's highest award, to Dr. E. G. Locke, Director of the USFPL.

Assistant Secretary of Agriculture, Ervin L. Peterson, addressed a capacity crowd of 500 at the FPL Golden Anniversary Banquet, June 2, 1960, in Great Hall of the University of Wisconsin's Memorial Union.

Golden Anniversary of Madison FPL Attended By Heads of Industry, Government

The United States Forest Products Laboratory in Madison, Wis., was praised by industry leaders and state officials for its part in modernizing the forest industries during the celebration of its Golden Anniversary as the world's first institution in this field.

General Assembly

On Friday morning, June 3, a General Assembly convened in the Wisconsin Memorial Union Theater. The speakers were President Elvehjem; Frederick K. Weyerhaeuser, Chairman of the Board of the Weyerhaeuser Co.; Howard E. Whitaker, President, American Pulp and Paper Association; W. E. Difford, Executive Vice-President of the Douglas Fir Plywood Association; and Samuel Lenher, Vice-President of E. I. duPont de Nemours, Inc.

Weyerhaeuser Lauds Glue

Weyerhaeuser emphasized that lumber's markets have been shrinking as much because of newer wood products as because of other competing materials. He hailed the developing use of glues in wood products as perhaps the most important single development in the lumber industry to date.

Discussing the paper industry, Whitaker forecast, among other developments, a synthetic fiber reconstituted from wood cellulose to standard dimensions and properties, to control paper uniformity and stability.

Difford, Lenher Speak

Difford spoke on "Forest Products Research and the Plywood Industry," praising the Laboratory and calling for "a massive effort in pure and applied research," with the Madison Laboratory leading the way.

Chemical discovery of how to create the nitrogen compounds essential to use, Dr. Lenher predicted, may make it possible for man to make plants grow more efficiently. He called for fully practical ways to make wood dimensionally stable, fireproof and resistant to deterioration.

Governor's Luncheon

At the Governor's luncheon commemorating the anniversary, Fri. noon, Governor Gaylord Nelson traced the development of Wisconsin's conservation program over the past century. Stanton W. Mead, President of the Consolidated Water Power and Paper Co., introduced the Governor.

The three-day celebration began Thurs., June 2, with a banquet in the University of Wisconsin Memorial Union. Dr. Edward G. Locke, Director of the Laboratory, presided over the program, which included George A. Garratt, Dean of the Yale University School of Forestry as Master of Ceremonies.

Cline Gets Award

McGarvey Cline, first Director of the Madison FPL, was presented with a citation by Conrad A. Elvehjem, President of the University of Wisconsin, on behalf of the University.

A Distinguished Service Award was given to the Laboratory by Ernest C. Betts, Jr., Director of Personnel, USDA.

Chief of Forest Service Speaks

Ervin L. Peterson, Assistant Secretary of Agriculture, gave the main address of the evening. His talk was preceded by remarks from the Chief of the US Forest Service, Richard A. McArdle.

McArdle praised the Laboratory in fulfilling many of the aims of the forest research industry, but went on to say that this research is by no means finished. "Couple declining forest acreage with declining timber quality, and you have the best argument I know for accelerating forestry research of every kind," he stated.

Peterson's "Creative Forestry"

Mr. Peterson, in his speech, advocated "creative forestry." He stated that our competitive economy and not Governmental authority is the basis for creative forestry. A competitive private enterprise community "is a system where everyone cannot run first in every race, but one wherein everyone has opportunity to run. Moreover, the perpetuation of our private competitive enterprise economy is necessary to perpetuation of our free institutions—of representative Government itself."

Industry Awards Given

Six industry awards for research that led to outstanding industrial developments and products were given to the Laboratory Friday afternoon.

The Prefabricated Housing Plaque was presented by George E. Price for the Home Manufacturers Association. The Insulation Board Institute awarded the Laboratory an Insulating Board Scroll, with Robert A. LaCrosse making the presentation. American Paper and Pulp representative John R. Kimberly, gave a Semichemical Pulping Plaque. Frank J. Hanrahan awarded the Laboratory a Laminated Arches Plaque on behalf of the American Institute of Timber Construction, and Mr. Difford presented the Exterior Plywood plaque for the Douglas Fir Plywood Association.

"Opportunities for Graduate Studies in Forest Products"

That's the title of a booklet describing a new cooperative program between the U. of Wisconsin and the U.S. Forest Products Laboratory, Madison Wis. It is aimed at students looking for an institution with a unique combination of high academic standards and outstanding research facilities. It describes how a cooperative arrangement with the U. of Wisconsin makes it possible for a selected group of students to fit their graduate research into the framework of the Lab's program, leading to M.S. and Ph.D. degrees. Write, Director, U.S. Forest Products Lab., Madison, Wis.

Many visitors stopped to examine the well-planned displays during the three-day festivities marking the Golden anniversary of the Madison FPL. Special tours were conducted on Friday, June 3, for guests of the Laboratory. On Saturday afternoon, the Laboratory was open for public inspection.

Research at FPL of Canada Shows Log Waste, New Acid

Wood Left After Logging

The Vancouver Laboratory conducted a study in Alberta in cooperation with the Provincial Department of Lands and Forests to determine the volume and character of wood residues left on logging operations. The aim of this study was to provide factual information as a first step towards improved recovery methods and more effective utilization.

White spruce is the most important species in both boreal and sub-alpine forest regions, with lodgepole pine and balsam fir becoming increasingly important at the higher elevations. Wood utilization in both regions is predominantly confined to the production of lumber. However, the fact that one pulp mill is in operation at Hinton and others are being considered in other parts of the province, will influence utilization standards in the areas concerned.

Logging residues varied considerably between the two regions. They amounted to 7.0 per cent of the original stand volume in the boreal region, 17.8 per cent in the sub-alpine region, and averaged 12.4 per cent for the province. The high percentage of residues occurring in the sub-alpine region was due to the increased age of the stands with the accompanying decay, and the larger volume of pine and balsam, both of which mature at an earlier age than spruce.

Residue in tops accounted for over 50 per cent of the total, followed by sound wood left in standing defective trees of merchantable diameter. Waste left in high stumps was the smallest factor contributing to the total residue.

The results of this study showed that, although considerable volumes of sound wood are left after logging, most of it was too small or too defective for the economic production of lumber. However, as much of this residue is potentially useful material, with the growing demand for paper products and the construction of pulp mills a greater portion of the tree may be expected to be utilized.

Conversion Factors

Data collected for many years at the Vancouver Laboratory, have now been published as multilith V-1027, "Some Conversion Factors for British Columbia Forest Products" by F. W. Guernsey.

Data in the report include: (1) weights of primary forest products, (2) weights and volumes of secondary products, (3) residues, (4) yields, (5) cross-sectional areas of lumber, (6) calorific values, (7) moisture content determinations, (8) log scale formulae, (9) power equipvalents and (10) metric equivalents.

Stain of Exterior Cedar

The major component of the material leached from western red cedar wood by water is an exceedingly reactive organic acid. In discovering and isolating this new substance, chemists at the Vancouver Laboratory, named it plicatic acid because of its source in Thuja plicata.

Due to its unstable nature, a great deal of painstaking experimentation was required before plicatic acid could be isolated in pure form from the complex mixture of substances occurring with it in the extractives of cedar. In the course of this work a great deal of information about the properties of this chemical was acquired and much of this new knowledge has been useful in explaining some of the problems encountered in cedar utilization.

For example, one of these utilization problems is the brown stain which sometimes occurs on painted cedar exteriors. This stain has in the past been variously attributed to reaction of the paint with wood constituents, bleed through of wood resins, contamination with iron, etc. Now analyses have shown that a major part of the stain is plicatic acid and its decomposition products. Since plicatic acid is non-volatile and soluble only in water, the one way it could arrive on the paint surface would be in solution in water. Thus, the staining problem is clearly a moisture movement problem which can be corrected by better construction and finishing techniques.

New "Finishield" Gives Protection to Furniture

A revolutionary new finish for furniture, "Finishield" was announced by E. Howard Gatewood, executive vice president of the Fine Hardwoods Association. Maintaining the true beauty and authenticity of genuine fine veneers, "Finishield" offers new and excellent protection to furniture surfaces, and is highly resistant to abrasion, solvents and cigarette burns.

To be demonstrated at the National Association of Furniture Manufacturer's convention beginning August 27 in Chicago, Illinois, "Finishield" is a combination of two easily applied processes—either the new polyester or epoxy finishes resistant to abrasion and solvents, and a recently developed "Dri-Line" foil laminated directly beneath the veneer to distribute heat and avoid cigarette burn scars.

Object of 10 years research, the new finish was developed under the direction of the Association's Research Committee. "For the past two years," says Gatewood, "the Committee has worked with leading aluminum and finish companies, testing in independent laboratories, to develop a completely practical method for protecting furniture against uncontrollable accidents and wear. Final tests show that "Finishield" is both practical in manufacture and use and the Committee will offer its findings and process reports to the nation's manufacturers upon request."

Tests with various chemical formulae resulted in a successful combination of catalyst and sealer coat which permits the final surface finish to be applied with a single nozzle spray gun, eliminating any manufacturing problems. Used as a final coat on the surface, the new finish is resistant to abrasion and impervious to solvents such as alcohol, perfume and acetone. Competely adaptable to final finishing and polishing, "Finishield" may emerge in any state from dull to glossy finish.

FPRS Rocky Mountain Section held its second annual winter meeting at the new Wood Utilization Laboratory of Colorado State University, February 19. Papers on Adhesives Advancement, Marketing Research, Dimensional Variation in Lumber Manufacture, and Stumpage Sales were presented. Among the speakers were, l. to r., Thomas Schomberg, Douglas Knudson, Jay Hughes, Roland Bararger. Robert Miller, Frank Rovsek, Harry Troxell and Robert Bader.

SE Wood Pole Conference to Discuss Pine Pole Care

The Southeastern Wood Pole Conference, to be held Aug. 23-25, 1960, at the University of Florida, will present current information on the inspection and maintenance of Southern Yellow Pine poles in utility systems.

Practical methods of detecting deterioration in wood poles, the selection of the best remedial treatment to prolong pole life, the making of sound economic choices between preserving in place, stubbing, or replacing existing poles will be stressed. Proper decisions based on these three factors can extend pole life and save operating utilities many thousands of dollars.

Managers, engineers, fiscal agents, purchasing agents and technical personnel in operating utilities as well as in wood treating and chemical companies, railroads and other large consumers of treated wood products, will find this instruction of value.

The registration fee is $25.00 per person. Copies of conference papers will be provided.

Complete information may be obtained by writing to Dr. Fairing at 807 Seagle Building, Gainesville, Fla.

Science Foundation Sends Dr. Lowe to Great Britain

Dr. Josiah L. Lowe, Professor of forest botany and one of the leading research scientists at the State University College of Forestry at Syracuse University, left for Great Britain early in May on a five-month National Science Foundation grant to continue his exploration of fungi causing rot in woods.

Dr. Lowe is recognized as a world authority on the genus Poria, a very important group of wood-rotting fungi.

The results of Dr. Lowe's five-month study will be published as part of a classification manual of fungi in North America. Dr. Lowe has been working on the manual for the past 15 years. The classification manual, when published, will be the only up-to-date manual of its kind. Dr. Lowe expects to complete the manual in 1966 or 1967.

Mid-West Section Gives Award

Charles L. Stayton, center, junior in Forestry at the University of Illinois, Champaign, was recently named the outstanding student in the field of wood technology and utilization in the UI Department of Forestry. This award, presented by the Mid-West Section of the Forest Products Research Society, is also based on scholarship, personality and promise of leadership. Profs. C. S. Walters (left) and J. N. Spaeth, head of the department, present a copy of the **Forest Products Journal** to Stayton as a symbol of the award.

Manson Chosen President of California FPL Council

Byrne Manson, director of engineering and research for Simpson Redwood Company at Arcata, was elected president of the Technical Advisory Council to the University of California's Forest Products Laboratory during its spring meeting at the Richmond Field Station on Friday, May 13.

Other officers chosen were Dr. Howard S. Gardner, director of research and development for Fibreboard Paper Products Corporation at Antioch, California, vice president, and Warren A. Carleton, assistant manager of Winton Lumber Company at Martell, California, secretary.

Manson succeeded A. Bristow Hood, vice president and general manager of Ralph L. Smith, Lumber Company at Anderson, California, who is retiring from the Council.

Also leaving the Council serving three-year terms are Eddy S. Feldman, executive secretary of the Los Angeles Furniture Mart, who had been secretary of the group; Ben Benioff, partner in King & Benioff Structural Engineers at Sherman Oaks, California, and Russell Johnson, president of Union Lumber Company at San Francisco.

The Council was given a review of the research achievements of the Forest Products Laboratory during the past five years by Director Fred E. Dickinson. He recommended that the FPL initiate studies of wood product pathology and bacteriology within the next five years.

Amazon Forest Discussed At Fifth F.A.O. Congress

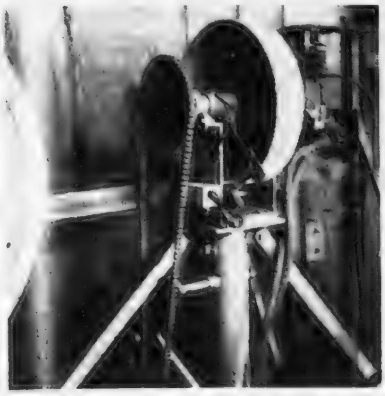
The wood supplies of the Amazon Basin, the world's largest tropical forest, will be the subject of a discussion by V. C. Hasek, a forestry at the Fifth World Forestry Congress in Seattle, Wash., Aug. 20 to Sept. 10, 1960.

Nearly 2,000 persons from more than 80 countries will participate in the two week Congress designed to advance the science and practice of forestry and to stimulate international cooperation in the development and use of the world's forest resources.

According to Mr. Hasek, a forestry expert working in Brazil for the Food and Agriculture Organization, there are 491 species of trees growing in Brazilian forests, yet 84 percent of these trees are unknown on the world's timber markets because of problems of cutting on the Amazon. A great percentage of these trees that are too dense to float to market and a large number almost too tough for modern sawmills to cut are not reaching world markets due to lack of proper harvesting equipment.

Mr. Hasek feels that the tropical sawmill should be a self-contained unit because few facilities necessary to the sawmill operation exist in outlying regions. This sawmill should be built as a big permanent enterprise in order to justify the heavy expenditure of building roads, housing and other facilities. Only a large permanent sawmill would be sufficiently interested in the quality of the future forest to finance reforestation of areas being logged and thus contribute to development of the region.

NEW PRODUCTS and Literature



Sawyer Controlled Setworks Cuts Costs For Small Mills

A new sawyer controlled setworks, the MATER AUTO–DIALSET has been made available by Mater Machine Works, Inc., Corvallis, Oregon. The Mater Auto-Dial-Set now enables the small mill to put a sawyer controlled pre-determined setworks on his carriage at about half the cost previously required.

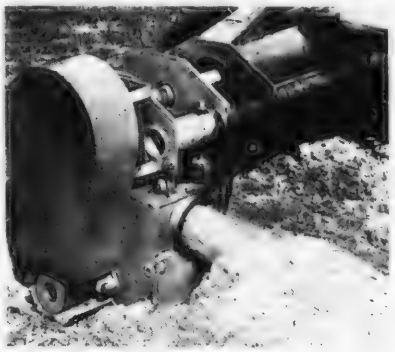
The Patented Auto-DialSet has only one moving mechanical part and the simplest electrical circuit possible. It is so simple that the small mill which avoided pre-determined setworks because it did not have an electrician available for maintenance can now enjoy the advantages of this type of setworks. The rugged units combines two previously separate parts in one: the carriage control unit is mounted in the Mater Aluminum Drum Dial. The entire setworks uses only one chain and sprocket drive.

Industron Corporation Elects Officers, Directors, at Meeting

Mr. Paul D. Zottu, President of Industron Corporation, 55 Needham Street,, Newton Highlands, Massachusetts, announced that stockholders at the annual meeting May 18, 1960 elected Bruce K. Heick to the position of Treasurer and Director and Mr. Herman Snyder to the position of Clerk and Director. Other Directors elected were Vernal E. Kezer, President of the Needham National Bank; John K. Dineen, Attorney in the firm of Weston, Patrick and Stevens; R. Wayne Homans, partner in the Investment firm of Schirmer Atherton and Co.; Paul D. Zottu, President of Industron Corporation.

Saw for Both Plywood, Solid Wood

New Double-Duty "A–80" Circular Plywood Saw announced by Atkins Division of the Borg–Warner Corporation believed to be the only blade of its type available, will cut up to 1-¼" plywood and up to 3" solid wood with glue-joint smoothness and less noise. Special side clearance grinding and heavy beveled, filed teeth are said to insure faster, splinter-free cutting in both ply and solid woods. Mirror-smooth, hard chrome finish and special expansion slots on the "A–80" reduce friction which, in turn, reduces heat and noise. In addition, an improved tempering process is said to permit more cuts between sharpenings and longer overall blade life. Complete details and prices can be obtained from Atkins hardware wholesalers or by writing the Atkins Saw Division, Borg–Warner Corporation, Indianapolis 25, Indiana.



"Stump Gobbler"

Blasting and burning of stumps are no longer necessary with the new "stump gobbler" tractor attachment by Myers-Sherman Co., Streator, Ill. The unit mounts on the rear of any standard tractor and takes power from the power takeoff shaft at 533 rpm. It chews up a stump in a few minutes with sixteen special saw blades.

Science Scholarships Announced

The Adhesive, Resin & Chemical Division of American–Marietta Co. has announced the winners of its annual Customer's Scholarships for fifteen studies in science at various western colleges. Awards of $250 each were presented to outstanding freshmen at the Universities of Washington, Idaho, Oregon, Washington State, British Columbia, Alberta, California; and Humboldt and Oregon State Colleges.

AAR Authorizes New Method to Handle RR Poles, Piling

An improved method of loading and bracing treated poles and piling on railroad flatcars and gondola cars developed by Signode Steel Strapping Co., has been approved and authorized by the Association of American Railroads for general use by Shippers. More than 20 months of development work, in cooperation with the AAR, and well over 200 experimental shipments preceded the formal acceptance.

In the new method, small overlapping section units of the total load are encircled with strapping in such a manner that these units interlock to form a tight mass. Each unitizing strap encircles a common layer of poles in the adjoining unit. As the poles "settle" in transit, they press on the straps, thus taking out any slack that might have developed, and help maintain the tension of those straps.

This method, in addition to insuring safe arrival, is economical. It utilizes 1-¼ inch heavy-duty strapping for bracing instead of the 2-inch straps called for previously by the AAR. Cost figure studies show that the smaller strapping size, and other economies, will result in savings of up to $4.50 per car.

Borden Co. Puts Out Directory

A new revised 12-page polymer directory and catalogue is being offered by The Borden Chemical Company. Intended primarily for research and professional use, the catalogue lists properties, end uses, and other technical data such as percent solids, viscosity, pH, particle size, percent free monomer, specific gravity, and weight per gallon for more than 150 Borden Chemical polymers. Write Department H, The Borden Chemical Company, 350 Madison Avenue, New York 17, N.Y.

Teco Announces New Catalog

A new comprehensive 8-page catalog on TECO timber connectors, framing devices and installation tools is now available, Timber Engineering Company has announced. Attractively illustrated, the new publication provides the architect, engineer and builder with complete specifications and details on the full line of TECO products.

Copies of the new TECO catalog are available free of charge and can be obtained by writing Timber Engineering Company, 1319 18th Street, N. W., Washington 6, D. C.

AITC Announces Revised Standard Appearance Grades

A revision of Standard Appearance Grades for glued laminated structural members has been announced by Frank J. Hanrahan, Executive Vice President of the American Institute of Timber Construction.

Appearance grades apply to the surfaces of glued laminated members. Three appearance grades, according to ATIC, fulfill nominal requirements.

The revised standard details the requirements necessary to qualify a glue laminated member for each of the three grades.

Single copies of the standard are available without charge from AITC, 1757 K St., N. W., Washington 6, D. C. Bulk price is $2.00 per hundred.

Raybond Electronics Begins Full Production After Fire

Raybond Electronics, Inc., is back in full production after the fire which destroyed its manufacturing area in Newton, Massachusetts, announced the President and General Manager, D. Racoosin. A new plant has been secured with an area four times the size of the previous plant. New machinery has been installed and greatly improved production and delivery facilities are now available. The new address is 930 Washington Street, Norwood, Massachusetts.

Double-Headed Chip Blanker

Faster production and increased profits are claimed for a new top-and-side chip-blanker made by Stetson-Ross. The double-headed chip blanker produces high-quality chips of the type preferred by pulp and paper manufacturers while easing production flow through the planer and matcher. It is adaptable to all makes of planers and matchers, and works well on fir, hemlock, spruce, or pine. For details write: Stetson–Ross Machine Co., Inc., 3200 First Avenue South, Seattle 4, Washington.

New Distributors For Pop Rivets

Three Los Angeles, California, distributors of "POP" rivets and tools, both manual and powered, are announced by the "POP" Rivet Division of United Shoe Machinery Corporation. They are Montroy Supply Company, Reliable Steel Supply Company, and The Bob Gosche Company. Montroy specializes in the electrical sign field; Reliable in heating, ventilating, and air conditioning; and Bob Gosche in the automotive field.

New Data Offered on Plywood Sheathing

Douglas Fir Plywood Association, Tacoma 2, Wash. has completed a series of tests showing that 3/8-inch room sheathing is fully adequate in certain applications when the panels are laid with the face grain parallel to framing members.

Normally, such panels are applied with the face grain perpendicular to framing members. It is occasionally economically desirable to lay plywood the other way as in certain types of stress skin panels. The test methods and results are outlined in detail in DFPA Laboratory Bulletin 6-A. Write Technical Department, Douglas Fir Plywood Association, Tacoma 2, Washington.

New Sheet-Board Publication

A technical publication describing the appearance, manufacture and use of Sheet-Board, has been annnounced by the Western Pine Association.

Sheet-Board is a modular panel for use in roof, floor and sidewall sheathing with other possible uses in construction, farm, home and industry. It is actually standard thickness sawn lumber boards laid up side by side and glue-bonded by heat and pressure between sheets of heavy kraft paper. The finished panel product enhances lumber's built-in strength.

A copy of the publication will be sent on request. Write Western Pine Association, 510 Yeon Building, Portland 4, Oregon.

If it's a question about wood preservatives...

See the man from WOOD TREATING

PENTACHOROPHENOL
Recognized as the leading preservative for protecting wood against decay and rot, termites and other wood-boring insects. Clean... won't stain... contains 5% Pentachlorophenol in a solvent base.

NOXTANE
Controls ugly blue-black sap stains and mold. Keeps lumber bright and clear... stops costly degrading. Contains no arsenic or mercury—non-irritating and dustless—resists leaching from rain.

PRESSTREAT
Combination of PENTA **plus** water repellents for pressure treatment of lumber. Provides super above-and-below-ground protection against termites, other wood-boring insects, decay and fungus.

WOODTREAT A
A 10% Penta emulsion paste. Gives maximum protection to standing poles, piling, cutoffs, structural timbers. Applied by hand scoop, brush, paddle or mechanical spray. Clean to handle... not highly toxic.

TECHNICAL COUNSEL
Experienced specialists **plus** the most modern and complete laboratory facilities, are available for counsel and help on any wood preservation problem.

For more information, write or phone...

Wood Treating Chemicals Co.

3137 Southwest Ave. • St. Louis 10, Mo.

EMPLOYMENT *Opportunities*

Positions Offered

E-3[illegible]—Wanted: Sales Engineer. Self-pro[illegible]lled, creative salesman, with structur[illegible] engineering degree and experience —[illegible] trainee for six months in Seattle, the[illegible] development of market for a plant in [illegible]alifornia—for growing components manufacturer. (June)

E-3[illegible]—Wanted: Sales Manager for Saw Mill Machinery Manufacturer. Man of proven administrative ability to direct northwest sales. Also supervise engineering and customer service. Coordinate efforts of sales engineers. Determine policies and handle top-level customer contacts. Send complete resume of education, experience, salary, references, etc. All replies confidential. Our employees know of this opening. (June)

E-393—State Forest Service in the South has an opening for a qualified Wood Technologist or Forest Utilization Specialist. Recent graduates or men with modest experience in the field acceptable. Applicants must hold Master's Degree, be interested in research work, and capable of working with private industry. Wood utilization experience will be accepted in lieu of educational requirement in exceptional instances. (June)

Employment Wanted

600—Sales, promotion, or public relations position with opportunity for growth and advancement wanted by wood technologist. Experience in sales, technical service, quality control, R & D, plywood and adhesives. B.S. in Forest Products from University of Washington. Prefer West. Age 32, married, 3 children. Resume on request. (June)

607—Wood Technology major. Will graduate in June, 1960, from University of Michigan, wants position, preferably in the general West. Second field, Forestry. Is particularly interested in adhesives and particle board, kiln drying, and timber mechanics. (June)

608—Dissatisfied with present job, Forestry School graduate wants job in Product Development, Production, or of other technical nature. Little or no traveling. (June)

610—Registered Professional Engineer; several degrees; 47; excellent health. Years' experience in design and research of all types of buildings and prefabrication of buildings. Cost and quality conscious, inventive, also experienced as chief engineer and head of design department. Seeks permanent responsible position. (June)

613—Prof. Engr. (Cal. Tech.) B.S., M.S. Mech. Engr. Been in top management 13 years in furniture, cabinet, fixture and architectural, door, machinery and grain printing plants, looking for top job or wishes to represent Eastern manufacturer on the West Coast. (July)

614—Wood technologist with five years laboratory, field service experience with large adhesive company. Wants development or production work in particle board or other forest products industry. B.S. in Forestry, M.S. in Wood Utilization. Age 32. (July)

615—Wood Technologist soon to receive Master's Degree desires position in basic wood drying research. Experience includes several wood drying studies and thesis work. Primarily concerned with stresses and their removal. Will be available beginning in September. Secondary interest in wood quality-tree growth studies or particle board research. Strong background in forestry. (July)

POSITION OFFERED

We have an immediate opening for a University graduate in Wood Utilization, Forest Products or a Mechanical or Industrial Engineer with experience in Flakeboard, particle board or related products.

Experience and/or strong interest in Production is desirable, but qualifications will determine final selection.

Position: Assistant Production Superintendent in a new and expanding Flakeboard Plant, an integral part of the Building Boards Division of the sixth largest Paper Company in the United States.

Salary dependent upon qualifications.

Please send resume of education and experience to:

MR. CHALMERS E. BARR
Personnel Manager
WEST VIRGINIA PULP AND PAPER
[illegible]RONE, PENNA.

ABITIBI
COMPOSITION BOARD
RESEARCH AND DEVELOPMENT

The Central Research Division of the Abitibi Power and Paper Company, Limited, which has particle board, insulation board and hardboard operations in the U. S. and Canada, is enlarging its Panelboard Department.

We have openings for University graduates in basic research, process development, new product development and application studies.

We invite applications from both new graduates and experienced men, who are interested in the expanding field of composition board and have initiative and an inquiring mind.

Salary dependent on qualifications.

Please send resume of education and experience to:

DR. RODGER M. DORLAND
Director of Research
Central Research Division
Abitibi Power & Paper Company, Limited
Sault Ste. Marie, Ontario, Canada

What's New in *Technical Publications*

Single Copies of the Following Reports are Available Free Upon Request from the Director, U.S. Forest Products Laboratory, Madison 5, Wis.

A new report, "**Heating Veneer Bolts to Improve Quality of Douglas-Fir Plywood,**" No. 2182, is one of six new or revised reports recently issued by the U. S. Forest Products Laboratory here. It describes three methods of heating Douglas-fir bolts to improve veneer quality and discusses the advantages and limitations of each.

Report No. 2183, "Symposium on Adhesives for the Wood Industry," contains the proceedings of a symposium that was sponsored jointly by the Forest Products Laboratory and the Products and Research Committee of the National Lumber Manufacturers Association on January 13-15, 1960.

Report No. 2184, "Feed-Speed Relationships for Cutting Tools," explains the use of a chart, included with the report, for computing the interrelationships between the number of cutting edges of the tool, its speed, and the feed per cutting edge or per minute.

A discussion of groundwood and sulfate pulping experiments made on wood from pole-blighted and healthy western white pine is contained in a report, "**The Groundwood and Sulfate Pulping of Pole-Blighted and Healthy Western White Pine,**" No. 2185.

A report entitled "**Your Career in Forest Products Research No. 2186,** highlights some of the opportunities, advantages, and qualifications for the individual considering a vocation dedicated to scientific research in the forest products field.

EMPLOYMENT OFFERED

B.S. in Wood Technology or Wood Utilization to train in Production. Plant located Gulf, South.

Send replies to:

E-394, Employment Service
FOREST PRODUCTS RESEARCH SOCIETY
417 North Walnut Street
Madison 5, Wisconsin

(Professional Card)

MATER ENGINEERING

Professional consulting engineers for the forest products industry.
Sawmill automation, design, modernization, integrated plants, complete technical and economic studies.

P. O. Box 410
CORVALLIS, OREGON
Phone Plaza 3-7335

91 NEW OR TRANSFER MEMBERS IN MAY

Section Officers Please Take Note. We are going to publish each month all of the NEW or Transferred-into-the-Section Members. Please adjust your records, and gear to the most concerted New Membership Activity in FPRS history!

CAROLINA–CHESAPEAKE

John A. Brown, R. 1, Box 577, Spruce Pine, N. C.
E. V. Bulleit, Mgr., Wood Mosaic Corp., P. O. Box 9058, Huntington 4, W. Va.
Hubert T Dudley, 629 North Ave., P. O. Box 1207, Elkins, W. Va.
Soetrisno Hadi, Dept. of Plant Pathology, N. C. State College, Raleigh, N. C.
Norris Clarke Hatcher, Jr., Drexel Furniture Co., Drexel, N. C.
Frank B. Spires, Box 468, Conway, N. C.

EASTERN CANADIAN

Wm. Barford, Editor, Canada Lumberman, 1450 Don Mills Road, Don Mills, Ontario, Can.
Murray–Brantford Limited, Attn: J. E. Cash, P. O. Box 10, Thorold, Ontario, Can.
Wilburt L. Canniff, Box 395, Belleville, Ontario, Can.
J. C. Copeland, International Plywoods Ltd., Gatineau, Quebec, Can.
Mr. Jean J. Guay, Osmose Wood Preserving Co. of Can. Ltd., 2286 Marcil Ave., Montreal 28, Quebec, Can.
E. L. Kempthorne, Dring Laminated Structures Ltd., Boissevain, Manitoba, Can.
Robert Keen, Pulp & Paper Research Institute of Canada, 3420 University Street, Montreal 2, Can.
William E. Kilgour, J. W. Kilgour & Bro. Ltd., 15 St. Lawrence Street, Beauharnois, Quebec, Can.
R. W. L. Laidlaw, 50 Oak Street, Weston, Ontario, Can.
D. C. Nasmith, C. Lloyd & Son Ltd., Wingham, Ontario, Can.
R. M. Stephenson, 1203 Fleet Ave., Winnipeg 9, Manitoba, Can.

GREAT LAKES

O. B. Eustis, % Abitibi Corp., Alpena, Mich.
R. Ken Holden, Suite 11, Nor-Way Bldg., 20211 Greenfield, Detroit 35, Mich.
Carl A. Johnson, Owens–Illinois Glass Company, 1700 North Westwood Ave., Toledo 7, Ohio.
W. E. Larson, Fine Arts Furn. Co., 802 Monroe Ave., N., Grand Rapids 2, Mich.
Thomas J Pilliod, Jr., The Pilloid Cabinet Company, 105–117 Woodland Ave., Swanton, Ohio.
Jacob Pos, 218 Gunson St., East Lansing, Mich.
James Arthur Price, 120½ So. Waverly Rd., Lansing, Mich.
Gerald E. Sprenger, 704 W. "A" Street, Iron Mountain, Mich.

INLAND EMPIRE

Richard W. Bruce, Dept. of Forestry, Washington State University, Pullman, Wash.

MID-SOUTH

Montgomery R. Childs, 1408 Diana Drive, Lufkin, Tex.
Poo Chow, P. O. Box 5818, L.S.U., Baton Rouge 3, La.
Williiam S. Cockroft, The Frank A. Conkling Co., Box 7464, Waco, Tex.
Peter J. Fogg, P. O. Box 6182, University Sta., Baton Rouge 3, La.
Irwin Francis Grillot, P. O. Box 202, W. T. Carter & Bro., Camden (Polk County), Tex.
Milton C. Picard, 1909 Sterick Bldg., Memphis, Tenn.
Poinsett Lumber & Manufacturing Co., Attn: J. A. Crozier, Trumann, Ark.
James H. Zeagler, % White House Apts., Ruston, La.

MID-WEST

John B. Armstrong, Webcor, Incorporated, 5610 W. Bloomingdale, Chicago 39, Ill.
Robert T. Miller, General Sales Manager, Wisconsin Wood Products Corp., Phillips, Wis.
J. R. Sterle, Market Division, Caterpillar Tractor Co., Peoria, Ill.
Henry J. Voorhees, National Lumber Manufacturers Assoc., 176 West Adams St., Chicago 3, Ill.

NORTHEAST

George Bonsall, % Bro–Dart Industries, 56 Earl Street, Newark 5, N. J.
Matthew J. Bruccoli, Cleworth Publishing Co., One River Road, Cos Cob, Conn.
Carl E. Darrow, National Lumber Manufacturers Assoc., Salmon Towers, 11 W. 42nd St., New York, N. Y.
Victor S. DeLan, Jr., 26 Pine Court, Masonite Corp., Buffalo 26, N. Y.
Robert P. DeMarco, Massachusetts Institute of Technology, Department of Civil & Sanitary Engr., Cambridge 39, Mass.
John Ekwall, 217 Washington Ave., Bennington, Vt.
George Gettens, 59 Willow Street, Leominster, Mass.
Library Department, Nopco Chemical Company, Harrison, N. J.
Peter Cooper Corp., Attn: Robert G. Gill, Gowanda, N. Y.
W. S. Sloatman, Jr., American Cyanamid Company, 30 Rockefeller Plaza, New York 20, N. Y.
White Mills Handle Co., Attn: Dale E. Wolfe, P. O. Box 73, White Mills, Pa.

NORTHERN CALIFORNIA

Charles H. Beacon, Boldt–Beacon Lbr. Co., 2 W. Cutting Blvd., Richmond, Calif.
Charles C. Brown, Harbor Kiln Co., 1901 Shareline Drive, Apt. 307, Alameda, Calif.
A. B. Burdick, Tri-State Plywood Co., P. O. Box 519, Santa Clara, Calif.
Robert J. Clark, Box 649, Reno, Nev.
Ivory Pine Co. of Calif., Attn: Peter Field, Box 305, Dinuba, Calif.
Library, Dept. of Fish & Game & Dept. of Natural Resources, State Office Bldg. No. 1, Sacramento 14, Calif.
Wesley W. Page, 1000 16th St., San Francisco, Calif.
Roy E. Wright, % Phila. Quartz of Calif., 7th & Grayson St., Berkeley 2, Calif.

OHIO VALLEY

J. F. Burrell, Editor, Plywood, Publishers Building, 3516 N. College Ave., Indianapolis 5, Ind.
D. C. Carey, 3504 Hillsboro Ct., Louisville 7, Ky.
Charles C. Dieckmann, % Smith Cabinet Co., Inc., Salem, Ind.
Hayden E. Meeker, 3732 Lovell Ave., Cincinnati 11, Ohio.

PACIFIC NORTHWEST

Harry H. Bartels, 3630 Glen Oak Drive, Eugene, Ore.
Michael Wm. Bodnar, 970 Burrard St., Vancouver 1, B. C., Can.
Charles H. Burrows, Forest Research Center, P. O. Box 571, Corvallis, Ore.
Robert J. Crawford, Box 703, Oakridge, Ore.
Virgil C. Davis, Georgia–Pacific Timber Co., P. O. Box 248, Springfield, Ore.
H. W. Driehuyzen, 3585 West 34th Ave., Vancouver, B. C., Can.
Leif D. Espenas, Forest Research Center, P. O. Box 571, Corvallis, Ore.
William W. Gleaves, P. O. Box 533, Coos Bay, Ore.
Kenneth W. Guenther, Georgia Pacific, Equitable Bldg., Portland, Ore.
Julian R. Howarth, P. O. Box 494, McCleary, Wash.
D. W. Laishely, c/o 922 5th Street, Nelson, B. C., Can.
John W. McCollom, Al Disdero Lumber Co., 2100 S. W. 84th, Portland, Ore.
Donald J. Miller, Forest Research Center, P. O. Box 571, Corvallis, Ore.
Gilbert F. Oekerman, 1601 South Verde, Tacoma 5, Wash.
Eugene H. Schaudt, 110 E. 12th Ave., Eugene, Ore.
J. D. Snodgrass, Forest Research Center, P. O. Box 571, Corvallis, Ore.
James R. Sweeten, 615 Montrose St., Port Alberni, B. C., Can.
Bert Tannenbaum, 1128 W. Spokane St., Seattle 4, Wash.
Dr. Jack W. Wilson, Dir. of Research & Deve. Div., Columbia Cellulose Co., Ltd., Prince Rupert, B. C., Can.

PACIFIC SOUTHWEST

James M. Rice, 3400 Egerer Pl., Fullerton, Calif.
Edward B. Westall, 911 Idllywild Dr., San Jacinto, Calif.

ROCKY MOUNTAIN

Philip M. Opsal, 621 Skyline Drive, Fort Collins, Colo.

SOUTHEASTERN

W. A. Campbell, 225 King Ave., Athens, Ga.
J. C. Milliner, P. O. Box 1005, Savannah, Ga.
Lynn Walker, 7837A, Engineering & Physics Librarian, 400 E. & I. Building, University of Florida, Gainesville, Fla.

UPPER MISSISSIPPI

Bennie A. Bendtsen, 2442 Rice Street, St. Paul 17, Minn.
Harlan G. Freeman, % Louis Freeman, 2936 36th Ave., South Minneapolis, Minn.
Richard A. Fylstra, Rilco Laminated Products, St. Paul, Minn.
M. C. Gomber, Goodman Lumber Division, Calumet & Hecla, Inc., Goodman, Wis.
Richard Arthur Horn, 3204—21 St. Ave. So., Minneapolis 7, Minn.

NAMES in the NEWS

Richard F. Catchpole has been named code engineer for the Insulation Board Institute, **Charles M. Gray,** IBI manager announced. Catchpole formerly was regional manager of building code services for the NLMA in Chicago.

Appointment of **Robert H. Devine** as Assistant Vice President, in the Wood Preserving Division of Koppers Company, Inc. was told by **Douglas Gray, Jr.,** Vice President and Division General Manager.

Harold H. Biswell, professor of forestry at the University of California, Berkeley, has been awarded a Guggenheim Fellowship and a Fulbright Scholarship for research and teaching in the field of range management. Under the terms of the Guggenheim Fellowship, Biswell will study the historical role of fire in the development and structure of grass, brush and forests in regions with Mediterranean climate.

Ward Mayer, Chairman of the Board of Timber Structures, Inc., Portland, Ore., was re-elected president of American Institute of Timber Construction at the Institute's eighth annual meeting in San Francisco, Frank J. Hanrahan, Executive Vice President of AITC reported.

H. L. Schmidt, Jr., general manager of the Coatings and Adhesives Department of the Borden Chemical Company, A Division of The Borden Company, released news of the appointment of **Seymour D. Kirsch** as Development Manager, **Robert E. Munsell** as North East Regional Sales Manager, and **James H. Christopher, Jr.** as Sales Manager

William Van Natta has been named district sales manager—Structural Products Division, National Starch and Chemical Corporation, with responsibility for sales in New York, New Jersey, Pennsylvania, eastern Ohio and Maryland.

Donald A. Jaenicke, has been named director of the Special Projects Department of the Douglas Fir Plywood Association of Tacoma, Wash., Executive Vice President W. E. Difford stated. This new department will have responsibility for locating and exploring new potential markets for products of the plywood industry, particularly in the leisure field.

Appointment of **Dr. Carl H. Stoltenberg** as head of the department of forestry at Iowa State University was announced by the University following approval by the State Board of Regents.

Roy N. Propst, Jr. has been recently elected Assistant Vice President of R. Hoe & Co., Inc., according to William **A. Harloe,** Vice President. Propst will be in charge of the Saw Division's West Coast operations.

Announcement of the appointment of **S. W. (Sam) Loiry** as General Sales Manager, Soderhamn Machine Manufacturing Company, Talladega, Ala., was made by **Gus Jacobson,** President.

FPRS FOREST PRODUCTS JOURNAL VOL. X. NO. 6 JUNE. 1960

Water Sprays Protect Hardwood Logs

FROM STAIN AND DECAY

PAUL H. LANE
Wausau Research Center, Lake States Forest Experiment Station
and
THEODORE C. SCHEFFER
Forest Products Laboratory,[2] Forest Service U. S. Department of Agriculture

Winter-cut birch and maple logs deck-stored under water sprays from April to early October were free from decay and fungus stain. Unsprayed logs had from 7 to 10 inches of rot in the log ends, and veneer sheets showed stain had penetrated 21 to 42 inches.

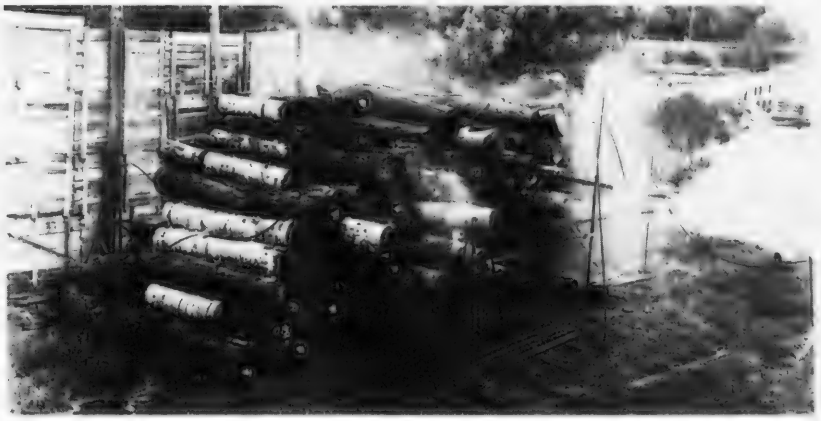


Fig. 1.—Pile No. 1, logs sprayed continuously on top and ends from April 20, to October 6, 1959. For this and the other sprayed piles, ¾-inch plastic pipe and wide-angle nozzles of the roof-cooling type were used.

DECAY AND STAIN ARE IMPORTANT sources of waste or degrade in hardwood logs decked on storage yards during warm weather. The problem is particularly serious in high-value hardwood veneer logs. Stain occurs in two forms: fungus discoloration and nonfungus discoloration (1,2,5,6)[3]. The nonfungus discloration, known as chemical or oxidation stain, results from exposure of the green wood to the air (analogous to the browning of an apple when it is opened).

Three basic control measures are commonly used to prevent or retard these defects in logs of northern hardwoods: (1) cold storage, (2) application of toxic chemicals, and (3) immersion in ponds or wetting under sprays.

In cold climates, a few plants have successfully stored frozen logs through the summer months by covering them with mill waste, such as sawdust or chips. This method is expensive for any large volume of wood and subject to many uncontrollable conditions.

The Authors: Paul Lane, Forester in Charge at the Wausau Center, has been in wood utilization research at the Lake States Station for 5 years. Theodore Scheffer, Pathologist, has been with the Pathology Section of the USFPL since 19[illegible].

Toxic chemicals, combined with an end coating to prevent checking, provide good protection if properly applied. They must be applied promptly in warm weather, however, because they are not effective once infection has occurred. Moreover, chemical treatment is ineffective on some hardwood species, such as beech and black oak (5).

Underwater storage is generally effective, but has a number of limitations. Ponds are expensive to build and maintain and the cost of handling logs in and out may run as high as $25 per MBM (4). The exposed portions of floating logs are subject to stain and decay, and the wood may acquire an objectionable grayish discoloration during prolonged pond storage if an appreciable amount of iron is present in the water. Furthermore, in the case of certain western pines, bacteria in the pond water tend to make the wood excessively absorptive (3).

Spraying decked logs with water has been used successfully, though to a limited extent, in the United States to protect western softwoods and northern hardwoods from stains, decay, and end checking (4,7,8). Little is known, however, about the basic requirements for successful spraying or, quantitatively, about the effectiveness of spraying to prevent the development of chemical or oxidation stains prevalent in hardwoods.

In 1959, the U.S. Forest Service in cooperation with the Birch Club, an association of hardwood veneer manufacturers in Wisconsin and Michigan, made a study of water spraying on four important hardwood species—yellow birch (*Betula alleghaniensis* Britton), white birch (*Betula papyrifera* Marsh.), hard maple (*Acer saccharum* Marsh.), and soft maple (*Acer saccharinum* L.). The findings are the subject of this report.

Acknowledgment is made to the following persons for their valuable help in carrying out the study: The Forest Veneer Company, Antigo, Wis.; Richard M. Marden and James C. Ward, Technologists, Wausau Research Center, and Joe W. Clark, Pathologist, Forest Products Laboratory.

Purpose of the Study

The principal objective of this study was to determine if hardwood logs cut during the winter could be protected from stain and decay during warm weather by several methods of spraying and what factors might be most involved in determining successful treatment. Besides the method of spraying, a point of special interest was the effect of delaying the spraying until late spring.

[1] Presented at Session XIII, Logging, FPRS 14th Annual Meeting, June 8, 1960, in Montreal, Canada.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

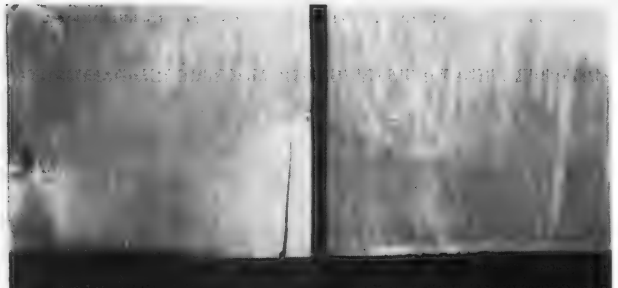


Fig. 2.—Principal defects in birch veneer. Upper left: light chemical stain, with darker fungus stain near end of sheet; upper right: dark chemical stain; lower left: heat stain—this stain resembled light chemical stain but occurred only in the mill; lower right: rot.

Fig. 3.—Principal defects observed in maple veneer. Upper left: light, bluish-gray chemical stain; upper right: light brown chemical stain (abnormally dark in the photograph); lower left: dark fungus stain; lower right: rot.

Procedure

Five experimental piles of winter-cut veneer logs were set up on the yard of the Frost Veneer Company. All piles were oriented in a north–south direction. Spraying equipment consisted principally of nozzles attached to ¾-inch plastic pipe as shown in figure 1. Nozzles were the wide-angle, roof-cooling type, providing a fine mist spray. Each nozzle covered a circular area about 14 feet in diameter and delivered about three-fourths of a gallon per minute at 10 pounds pressure per square inch. Water was supplied from the Antigo municipal system. Spraying was started on April 20, and continued until October 6, 1959. Conditions of the respective piles were as follows:

Pile No. 1.—Twenty-five logs each of yellow birch, white birch, hard maple, and soft maple. Sprayed continuously on all surfaces. Temperature at center of pile recorded continuously by recording thermometer.

Pile No. 2.—Four logs each of the four species. Sprayed continuously on ends only. Center of pile covered with plastic to prevent wetting by drifting spray.

Pile No. 3.—Four logs each of the four species. Wetted from the top, intermittently by 6-hour cycling.

Pile No. 4.—Four logs each of the four species. Wetted from the top, intermittently by 12-hour cycling of sprays. Sprays on during day—off at night.

Pile No. 5.—Control pile. Three logs each of the four species. Not sprayed or otherwise protected.

Delayed Spraying: On May 15, 1959, four logs each of yellow birch, white birch, and hard maple were added to pile No. 1. Four more logs each of these three species were similarly added on June 1, and July 1, 1959. In all cases, the logs were winter-cut, like those wetted from the start, and they were decked on the yard without protection prior to addition to pile No. 1.

The principal objective of the delayed spraying was to determine just how late winter-cut logs could be placed under the sprays without incurring serious degrade. In this connection, an answer was sought to the question of whether spraying would stop the spread of fungus stain and/or decay once it got established.

Analysis of Data: Sample bolts from each pile were cut into veneer for evaluation at the conclusion of spraying in October. Observations were confined to the condition of the sapwood, since no detectable changes occurred in the heartwood of logs in any of the four sprayed piles. Sapwood condition was determined from two sheets of veneer cut from each sample bolt. The sheets were selected at depths of about 1/3 and 2/3 of the sapwood thickness. Each sheet represented one complete rotation of the bolt.

Three types of storage defects were recorded: (1) light stain, (2) dark stain, and (3) rot. Light stain was defined as being acceptable to a limited extent in the unselect grade of commercial veneer, but not acceptable in the white grade. The dark stain was of sufficient intensity as to be acceptable only for core stock. All staining of any consequence in the yellow and white birch, and light staining in the hard and soft maple were of the chemical type—harmless except for objectionable color. The dark stain in the maple, however, was caused by dark-colored fungi that tended to make the veneer brash as well as discolored.

The distinction between light and dark stain in the birch veneer was not sharply defined, and sometimes it was difficult to classify. Examples of the different defects are shown in Figures 2 and 3.

A third kind of discoloration was observed but not recorded, since it would not occur in storage. This discoloration was called "heat stain" (see Fig. 2). It resembled the light chemical stain previously described, but developed only after the cool bolts were brought into the warm mill and left for several hours before cutting.

appeared on freshly-cut ends of the bolts as well as the ends exposed during yard storage.

The magnitude of each kind of defect is reported here in three ways: (1) by its frequency of occurrence in the sample veneer sheets, (2) by the average distance to which it had penetrated into the sheets from the originally exposed ends (corresponding to the depth of penetration into the log from the ends), and (3) by a combination of (2) and (3), giving a single figure—termed the index of size. The index of size was computed by multiplying the percentage of sheets affected by the average distance into the sheets and dividing by 50. An index of 100 might be obtained in unusual circumstances of prolonged storage in extraordinarily warm weather, causing the defect to occur, for example, in all sheets to an average depth of 50 inches.

Results

The results of the four types of spraying treatments are shown in table 1. These relate only to material from end bolts. All significant storage defects originated at the log ends, and wood 45 inches or more distant from the log ends was free of stain, hence the center bolt was undamaged.

Separate records were kept of the condition of veneer from north and south bolts. The data were combined here, however, since there was no evidence of important differences in results between the two bolts.

Unsprayed Log Controls: Veneer from the unsprayed control logs (pile 5) was severely discolored in all four wood species by either or both light and dark stain, and the stain was accompanied by rot of serious proportions. Light or dark stain occurred in practically all of the sheets, and the average distance of stain penetration into the sheets ranged mostly between 21 and 42 inches. The kind of amount of stain differed considerably among the four woods. Large amounts of both light and dark stain were present in the yellow birch, and moderate amounts in the white birch. A large amount of light, but no dark stain occurred in the hard maple, and only a negligible amount of light stain, but a large amount of dark occurred in the soft maple. These differences reflect variations in the composition of the woods that determine their susceptibility to chemical and fungus discoloration.

Rot was present in all sheets from the unsprayed logs. The average distances to which it penetrated visibly into the sheets were 8 inches in the yellow birth, 10 inches in the white birch, 8 inches in the hard maple, and 7 inches in the soft maple. Without a greater number of observations, it cannot be said that the species differences were representative. It is probably significant, however, that the rot extended deepest into the white birch, since in all previous storage tests, this wood has proved more susceptible to rotting than yellow birch or maples.

Sprayed Logs—Four Conditions: In contrast to the sizeable deterioration in the unsprayed logs, relatively little was observed in the sprayed logs. As was expected, continuous spraying with complete coverage of the logs (pile 1) gave the best protection. Defect indexes in yellow birch, white birch, hard maple, and soft maple were, respectively, light stain 5, 4, +, 4; dark stain 2, +, 0 +; and rot 0, 0, 0, 0. A comparatively large proportion of the logs incurred chemical stain despite spraying, but this was not serious, because penetration was usually no greater than about 3 inches, and in no case did it average more than 6 inches.

Storage defects found in the less thoroughly sprayed piles (Nos. 2, 3, and 4) were somewhat greater overall than they were in pile 1. It may be questioned, however, whether the differences associated with the manner of spraying were large enough to be of practical significance, since the superiority of continuous and complete spraying was noteworthy only with respect to the control of light stain in the white birch. This can be judged by comparing the indexes for light stain in piles 1, 2, 3, and 4, which were, respectively, 5, 7, 6, 7 in yellow birch; 4, 13 16 20 in white birch; +, 5, 1, 4 in hard maple; and 4, 1, 1, 1 in soft maple. Thus with the possible exception of the white

Table 1.—DEVELOPMENT OF DEFECTS IN WINTER-CUT LOGS STORED FROM APRIL UNTIL OCTOBER, WITH AND WITHOUT SPRAYING

Test pile and manner of spraying	No. of sample bolts veneered	Defects observed in sapwood veneer from end bolts: Light stain[1] Sheets affected Percent	Light stain[1] Average penetration from end of sheet In.	Light stain[1] Index of size[2]	Dark stain[1] Sheets affected Percent	Dark stain[1] Average penetration from end of sheet In.	Dark stain[1] Index of size[2]	Rot Sheets affected Percent	Rot Average penetration from end of sheet In.	Rot Index of size[2]
YELLOW BIRCH										
Pile No. 1—Sprayed continuously on top and log ends	10	50	5	5	15	6	2	0	0	0
Pile No. 2—Sprayed continuously on log ends	8	68	5	7	12	3	1	0	0	0
Pile No. 3—Sprayed intermittently on top at 6-hour intervals	8	56	5	6	43	3	2	0	0	0
Pile No. 4—Sprayed intermittently on top at 12-hour intervals; daytime	8	68	5	7	18	4	1	0	0	0
Pile No. 5—Not sprayed (control logs)	6	66	42	55	33	41	27	100	8	16
WHITE BIRCH										
Pile No. 1—Sprayed continuously on top and log ends	10	70	3	4	5	1	[3]+	0	0	0
Pile No. 2—Sprayed continuously on log ends	8	81	8	13	12	12	3	0	0	0
Pile No. 3—Sprayed intermittently on top at 6-hour intervals	8	74	11	16	62	3	4	50	1	1
Pile No. 4—Sprayed intermittently on top at 12-hour intervals; daytime	8	93	11	20	56	3	3	31	1	1
Pile No. 5—Not sprayed (control logs)	6	66	27	36	42	21	18	100	10	20
HARD MAPLE										
Pile No. 1—Sprayed continuously on top and log ends	10	15	1	[3]+	0	0	0	0	0	0
Pile No. 2—Sprayed continuously on log ends	8	62	4	5	0	0	0	0	0	0
Pile No. 3—Sprayed intermittently on top at 6-hour intervals	8	12	3	1	81	1	2	0	0	0
Pile No. 4—Sprayed intermittently on top at 12-hour intervals; daytime	8	62	3	4	87	2	3	0	0	0
Pile No. 5—Not sprayed (control logs)	6	100	28	56	0	0	0	100	8	16
SOFT MAPLE										
Pile No. 1—Sprayed continuously op top and log ends	10	70	3	4	10	1	[3]+	0	0	0
Pile No. 2—Sprayed continuously on log ends	8	25	2	1	87	4	7	0	0	0
Pile No. 3—Sprayed intermittently on top at 6-hour intervals	8	18	3	1	100	2	4	0	0	0
Pile No. 4—Sprayed intermittently on top at 12-hour intervals; daytime	8	31	2	1	75	1	2	0	0	0
Pile No. 5—Not sprayed (control logs)	6	8	3	[3]+	91	22	40	100	7	14

[1] With few exceptions, both the light and the dark stain in the birch sheets and the light stain in the maple sheets were chemical in nature, being caused by exposure of the log ends to the air. The dark stain in the maple was the result of infection by dark-colored fungi, which tended to weaken as well as discolor the wood.

[2] The index of size was computed by: 1/50 (Percent of sheets affected times Average distance into the sheets). Under unusual circumstances of prolonged storage in extraordinarily warm weather, an index of 100 might be obtained. This would be the case, for example, if all sheets from the end bolts had the defect and it penetrated to an average depth of 50 inches.

[3] Plus (+) denoted a value less than 0.5.

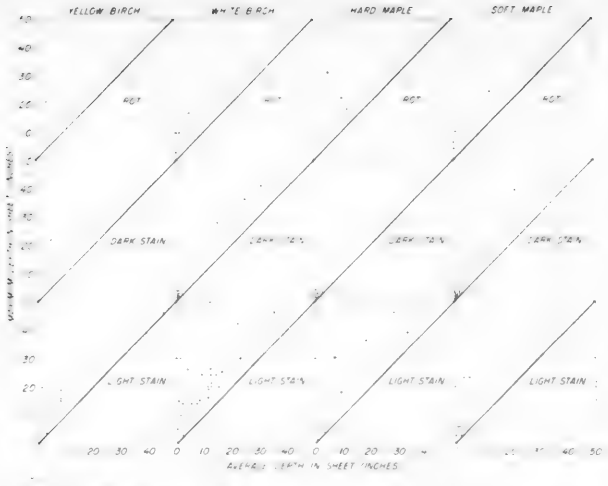


Fig. 4.—Relationships between maximum distance and average distance of defect penetration from the end of the veneer sheet. The 45-degree line shows location of average values and provides a reference for observing the amounts by which the maximum values exceed the averages.

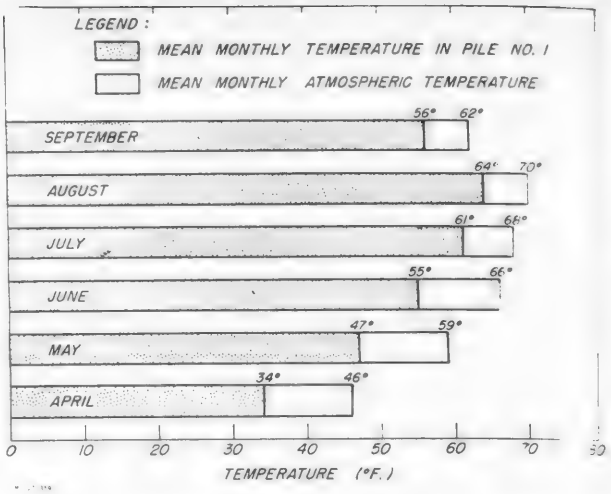


Fig. 5.—Temperatures at the center of pile No. 1 compared with nearby atmospheric temperatures. Pile temperatures from recording thermometer; atmospheric data from the weather station of the Wisconsin Conservation Department, Antigo, Wisconsin.

birch, it did not seem to make a great deal of difference whether the logs were sprayed continuously and completely (pile 1), continuously on the ends only (pile 2), completely at 6-hour intervals (pile 3), or completely at 12-hour intervals, with daytime application (pile 4).

Maximum Penetration of Defects: The foregoing comparisons refer to the average depth of penetration of stain or rot into the veneer bolt. The average depths indicate lengths that commonly might have to be trimmed from the veneer sheets in order to eliminate the most conspicuous or damaging of the affected areas. For some uses, however, it is necessary to eliminate also the streaks or tongues of altered wood that extend beyond the main body of of the effect. To provide information that might be useful in this connection, therefore, the maximum as well as the average penetration of a defect into the sheet was recorded. These data are presented in figure 4.

As might be anticipated, the maximum penetrations of stain and rot tended to show a correlation with the average amounts. It may be noted, however, that the relation was rather broad, especially so where the average penetrations were less than 10 inches. To aid in practical interpretation of the data, 45-degree lines were drawn on the figure to show where the average values would lie if they were located with reference to the vertical scale used for the maximum values. It might be concluded from the amounts by which the maximum values exceed the average values that, as a general rule, the maximum penetration of defect into the four species studied would commonly exceed the average by about 10 inches, at least where the average is 5 or more inches. The following may be noted as possible exceptions to this generality: Maximum penetration apparently may frequently exceed the average by 15 to 30 inches in the case of light stain in white birch; 15 to 20 inches in the case of rot in yellow birch, light stain in hard maple, and dark stain in soft maple; and 5 inches or less with dark stain in hard maple.

Effect of Delaying Spraying Until Warm Weather: It is generally recognized that rot and stain do not develop in logs during cold weather. Consequently, a reasonable certainty prevailed that winter-cut logs would be virtually free of such defects at the time they were placed in the sprayed piles, provided they went into the piles no later than the middle of April. There was, however, a question of whether longer delay in establishing spray protection could be tolerated without incurring serious damage. The uncertainty did not arise primarily because of the condition of the logs when piled, since this could be expected to be reasonably good until sometime in May, at least. Rather, it referred to

Table 2.—DEFECTS OBSERVED ON VENEER FROM WINTER-CUT LOGS PLACED IN PILE NO. 1 AFTER VARIOUS PERIODS OF DELAY

Date placed in pile No. 1	No. of sample bolts veneered	Defects observed in sapwood veneer from end bolts: Light stain[1] Sheets affected Percent	Light stain[1] Average penetration from end of sheet In.	Light stain[1] Index of size	Dark stain[1] Sheets affected Percent	Dark stain[1] Average penetration from end of sheet In.	Dark stain[1] Index of size	Rot[1] Sheets affected Percent	Rot[1] Average penetration from end of sheet In.	Rot[1] Index
YELLOW BIRCH										
April 18	10	50	5	5	15	6	2	0	0	
May 15	8	75	4	6	12	3	1	0	0	
June 1	8	62	4	5	0	0	0	0	0	
July 1	8	71	10	14	0	0	0	0	0	
WHITE BIRCH										
April 18	10	70	3	4	5	1	+[2]	0	0	
May 15	8	100	5	10	6	+[2]	+[2]	0	0	
June 1	8	75	12	18	12	4	1	0	0	
July 1	8	71	17	24	37	8	6	46	0.7	
HARD MAPLE										
April 18	10	15	1	+[2]	0	0	0	0	0	
May 15	8	62	1	1	0	0	0	0	0	
June 1	8	66	1	1	0	0	0	0	0	
July 1	8	81	2	2	18	0.5	+[2]	0	0	

[1] See footnotes of table 1 for comments regarding the stains and significance of the index of size.
[2] Plus (+) denotes a value less than 0.5.

whether the spraying could hold down to small proportions the defects already started, especially rot.

The results of the delayed spray protection, shown in table 2, indicated no consequential deterioration of any kind in logs held out of the spray until May 15, with the possible exception of light stain in the white birch, which at that time had a size index of 10. When the logs were held out until June 1, the light stain in white birch increased to an index of 18, but otherwise there still was no appreciable storage deterioration. When they were held out an additional month, until July 1, the only notable changes were an increase in the light stain of white birch to an index of 24 and the first occurrence of a significant amount (index 14) of light stain in the yellow birch. At this time, there continued to be negligible development of dark stain and rot.

That no more than a very slight amount of rot occurred in logs not sprayed until July 1 was unexpected. From the considerable amount of rot that typically occurs in northern hardwood logs during an entire warm season, it was assumed the rot would at least have begun to reach serious proportions by midsummer. That it did not do so cannot be attributed to any abnormality of temperature. U. S. Weather Bureau statistics for Antigo during the spraying period show that mean daily temperatures were slightly above normal and therefore could be expected to produce, if anything, a more rapid than usual development of stain and rot.

Temperatures in a sprayed Pile: Spraying is believed to make logs less susceptible to rot and fungus stains chiefly by keeping them cooler. Temperature data from this study, however, do not substantiate this belief. Figure 5 shows that mean monthly temperatures of the air at Antigo in the months of June, July, August, and September ranged from 62° to 70° F., and the corresponding average difference in temperature between the air and the inside of pile No. 1 was about 7 degrees. This reduction in temperature would not retard fungus attack more than 50 percent below the level to be expected in a dry pile at the prevailing air temperatures. Thus, temperatures in the pile were favorable for a substantial amount of rot despite the cooler environment. But since no rot developed in pile 1, it is evident that something considerably more than a cooling effect was derived from the spraying. Additional evidence that the cooling was of secondary importance is provided by the relatively good results in pile No. 2, obtained despite the fact that this pile was sprayed only at the ends and therefore was not significantly cooled.

Furthermore, the water used in this study came from deep wells and had a temperature of about 40° F. It can therefore be assumed that in practice the cooling would be even less than that obtained here, since most water used for spraying would be taken from ponds or streams.

Discussion

This study clearly shows that chemical and fungus stains and decay in hardwood logs of the four species involved can be readily controlled by continuous and complete spraying during warm weather. It also indicates the possibility of considerable latitude in the amount of wetting that may be relied on safely.

The evidence that the cooling effect is not a major factor in the protective influence of spraying establishes rather definitely that the primary mechanism of protection is the partial exclusion of air from the wood. Such an effect can account for the control of both chemical stain and damage in the forms of rot and fungus stain.

A certain minimum amount of oxygen is needed for the development of wood rotting and staining fungi, and parallel evidence in earlier studies indicates the probability that the chemical staining is the result of oxidation of certain wood elements (1,2).

A third factor, in the form of various micro-organisms, may also have had some influence on the protection afforded by spraying. A variety of micro-organisms of undetermined species occurred at the ends of most or all of the sprayed logs, producing a slimy surface. They did not penetrate far, consequently the infected wood ordinarily would be spurred off. Since these organisms were present at and near the surface of the logs in considerable profusion, it is possible that they may have aided in the control of rot and the deeper stains by consuming and, therefore, in effect, filtering out significant amounts of oxygen that otherwise would have entered the logs. Furthermore, they might have been antagonistic in some degree to the damaging species of wood-inhabiting fungi, thereby hindering infection.

Although cooling is not an essential factor and only the ends of the logs need be sprayed, spraying from the top of the pile probably will be generally favored because of the following advantages: (1) it requires no special stands to hold the spray nozzles, (2) it permits several ricks of logs to be bunched together, end-to-end, and (3) it makes it practicable to keep the pile height at a low enough level to permit stacking with mechanical equipment.

The generally favorable results obtained with the intermittent spraying, using cycles of 6 or 12 hours, indicate that if the log surfaces are thoroughly contacted, such discontinuous wetting may be employed without particular danger. Thus, it offers some advantage where water is short.

If intermittent spraying is to be used, a greater margin of safety possibly would be obtained by shortening the cycles, which would leave less time for the log surfaces to dry between periods of wetting. In addition, it might be possible to decrease the proportion of time allocated to the wet phase. Since the primary objective of the spraying is to restrict air to the logs by keeping the surfaces wet, it seems reasonable to expect that this could be done as effectively with wet-dry phases in the proportions of, say, 1 to 2 or 1 to 3, as with equal proportions if the cycles covered a number of minutes rather than hours. For example, 5 minutes of wetting and 10 or 15 minutes of drying might be acceptable if this would provide enough water to adequately wet the lowermost logs of the pile.

The results obtained with intermittent wetting also indicate that irregular dry phases of substantial length, such as often occur when the sprays become unbalanced by a strong wind, can be tolerated.

From the trials of delayed spraying, it is evident that winter-cut logs may be held without harm until at least about May 15 in climates like central Wisconsin.

In view of the comparatively good condition of logs held out of the spray until July 1, it must be concluded that the sizeable amounts of stain and rot found in the unsprayed logs (pile 5) at the end of the test were developed largely in July, August, and September, particularly in the last two months. Such rapid development of rot in the latter part of the season was necessarily dependent on a considerable amount of earlier, though invisible, infection. Temperatures in September apparently were comparatively favorable for rot. This is explainable, even though the air temperatures dropped into the sixties, on the assumption that temperatures inside the unsprayed logs were still conducive to substantial fungus activity because of the heat carried over from the preceding month.

The observations and conclusions of this study may not be wholly applicable to hardwoods of some other species than those considered here. The birches and maples have bark that provides a considerable natural barrier

against the entrance of fungi and air. Logs of certain woods, such as beech and black oak, do not have this advantage. It has not been ascertained whether this greater vulnerability of the bark would make logs materially more difficult to protect by spraying, although it obviously would be necessary to wet the entire log rather than just the ends. With normal wetting from the top of the pile, but perhaps with somewhat more care to avoid persistent dry areas resulting from changes in the spray pattern caused by a shifting wind, there is considerable reason to expect that spraying would be effective on such logs also.

Summary

Rot occurred in all the unsprayed logs to an average distance from the ends of 8 inches in the yellow birch and hard maple, 10 inches in the white birch, and 7 inches in the soft maple. Either light or dark stain was present in practically all of the sapwood veneer sheets from end bolts of all four woods, and it had penetrated into the sheets to average depths of approximately 21 to 42 inches. Dark stain was prominent in all the unsprayed wood except the hard maple, which had none. The light stains in all woods and the dark stain in birch were of chemical origin, resulting from exposure of the log ends to the air. The dark stain in the soft and hard maples was caused by dark-colored fungi and tended to weaken as well as discolor the wood.

Logs that were continuously sprayed on all surfaces remained free of rot and fungus-caused stain, and essentially free of chemical stain. Logs that were intermittently sprayed on all surfaces at 6-hour intervals or at 12-hour intervals—with the spraying being done during the daytime—were also well protected, except for the development of moderate amounts of light chemical stain in the white birch. Logs that were sprayed continuously at the ends only were essentially like those sprayed intermittently. This result, together with data showing that the cooling accomplished by wetting all surfaces was enough to account for only partial fungus control, indicated that the water provided protection primarily by its tendency to exclude air from the long ends, and only secondarily by its cooling effect.

Logs that were withheld from the spraying until as late as July 1 also came through in relatively good condition, which indicates that the defects observed in the unsprayed pile occurred largely after this time, particularly in August and September. To insure good results, however, spraying ordinarily should be initiated by about May 15 in areas where the climate is similar to central Wisconsin.

Literature Cited

1. Campbell, R. N. 1959. Fungus sap-stains of hardwoods. Southern Lumberman 199 (2489):115–120.
2. Clark, J. W. 1957. A gray, non-fu[n]gal seasoning discoloration of certain [red] oaks. Southern Lumberman 193(24[89]): 35–38.
3. Elwood, E. L. and B. A. Ecklund. [19]59. Pine logs in pine storage. Forest products Journal 9(9):283–292.
4. Isaacson, F. H. 1958. New water log spray method reduces log losses in storage. Wood and Wood Products 63(1):25–26, 60–62.
5. Scheffer, T. C. 1958. Control of decay and sap stains in logs and green lumber. U. S. Forest Products Laboratory Report No. 2107.
6. Scheffer, T. C. and R. M. Lindgren. 1940. Stains of sapwood and sapwood products and their control. U. S. Department of Agriculture Tech. Bulletin 714, 123 pp.
7. Stout, A. W. 1957. Water sprinkling protects decked logs. Western Pine Assoc. Res. Note No. 2.114.
8. Wright, E., A. C. Knauss, and R. M. Lindgren. 1959. Sprinkling to prevent decay in decked western hemlock logs. Research Note 177, Pacific Northwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture.

Transporting Wood Chips by Truck

Howard E. Lovejoy
Puget Sound Freight Lines, Seattle, Wash.

One key to profitable use of wood residues is the economic transport of chips and other salvaged materials. Here is a complete run-down on truck hauling, including types of hauling equipment, loading and unloading facilities, and an accurate cost analysis.

TRUCKS ARE DOING A BIG JOB TODAY in the hauling of wood chips. Our operation is just one of many, and we are transporting more than 2500 tons of wood chips daily to six mills in Western Washington and Oregon on hauls from 2 miles to 135 miles in length. Although there is nothing new about chip hauling by truck, it appears that the progress to date is only the beginning. As the effort has intensified to recover more usable wood fiber from our trees, trucks have become the indispensable link in the production line that now extends from forest to the finished product.

Wood Chips as a Cargo

Wood chips, produced in quantity, make a low value, dry bulk commodity of light density. They are usually accompanied by waste materials, and, if recovery is desired, economical handling can be accomplished with the same facilities and equipment used for transporting wood chips.

The weight of wood chips is dependent on moisture content to a large extent. Species, chip characteristics, and the degree of compaction are other factors. Weights are noted to vary from 3000 to 4000 pounds per 200 cubic foot unit for wood chips. wood waste or hogged fuel can exceed that range. Since weight is the limiting factor of payload, it appears obvious that dry chips are more economical to transport by truck than wet chips. The longer the haul, the more important this becomes.

Wood chips must be regarded as a low value raw material and, as such every consideration must be given to provide transportation at the lowest possible cost. Since this raw material is produced and consumed in great volume, it becomes profitable to provide elaborate facilities for most efficient handling.

The Author: Howard E. Lovejoy is Executive Vice-President and General Manager of Puget Sound Freight Lines. With more than 20 years experience in motor carrier management, he has been concentrating on carrier service for wood chips since 1953.

[1] Presented at the Wood Industries Conference in Portland, Oregon, September 10, 1959.

Fig. 1.—Six-unit dump trucks unloading on stockpile.

Fig. 2.—Overhead hoist, end-dump unloading facility.

There are some fundamental principles to observe if low cost transportation is to be achieved. Truck equipment is expensive and it is very important to plan any wood-chip haul to obtain the greatest amount of hauling for each and every piece of equipment. This is achieved by working maximum capacity equipment as many hours each day as possible and providing facilities for fast loading and unloading.

Selection of hauling equipment depends on many factors including length of haul, road conditions, legal weights and dimensions, and loading and unloading requirements.

Hauling Equipment

Body Type: The body type required for hauling wood chips must be large volume, usually open top, and specially equipped for unloading. Light weight is important if the haul is of any distance, particularly if it involves the use of public roads. A load cover is usually required to prevent spillage and wind loss.

The Dump Truck: Three axle, dual drive trucks, equipped with 5- to 6-unit dump bodies are capable of delivery to wood chip or hogged fuel stock piles. This type of equipment is easily maneuvered, has great tractive power and good stability. The principal advantage is fast unloading without special unloading facilities. This equipment is suitable for hauls of 15 miles or less, but it is not the most efficient method on high volume movements. Detachable bodies provide storage and loading for small producers at reasonable cost.

Self-dumping Semi-Trailer: There is one cable-dump semi-trailer equipped with a 10-unit body operating in Washington. The advantage of this combination is its ability to unload adjacent to a stockpile where crowded conditions and lack of facilities require such service. This equipment represents high first cost, high weight, and poor stability while unloading. Tractive ability is limited for stockpile operation.

End-dump Combinations: This type of equipment is generally unloaded by tilting on end by means of an overhead hoist although there are some hydraulically tilted ramps in use. The semi-trailer is undoubtedly the most popular combination because it is easy to handle and has good capacity. It is probably the most efficient except for longer hauls. Other combinations are truck and trailer, and doubles. These carry the load in two separate bodies and offer higher cubic and weight payloads. They have some disadvantages. The truck and trailer allows dual drive which is desirable for tractive ability but has the disadvantage of having the power unit integral with the body. This reduces flexibility. The doubles is extremely limited in backup ability and the motive power is usually transmitted through one axle only. Although single drive traction is not as good as dual drive, this does not matter too much on good roads. One disadvantage that is common to both the truck and trailer and doubles is that they have to be taken apart for unloading with consequent loss of time and the possibility of requiring extra help. Also the deficiencies in maneuvering ability impose additional requirements for accessibility at loading facilities.

Belt-unloading Semi-trailers: In recent years, belt-unloading equipment has been improved. The advantage of this equipment is the ability to self unload with low cost investment in unloading facilities. The rate of unloading is about one unit per minute which is quite adaptable to delivery direct to pulp mill conveyor systems. Delivery can also be made to pit or stockpile with minimum facility requirements. The belt in the trailer can be powered by gas engine, electric motor or hydraulic drive. The electric motor is economical and light weight but requires a power source which can be provided by a plug-in to mill power. Some belt trailers require water service for conveyor lubrication. The disadvantages to belt-unloading equipment are found in higher cost and maintenance, some loss in payload and additional time required for unloading. The loss of payload is quite important on long hauls and the unloading time is most important on short hauls.

Unloading Facilities

Stockpile: At mills where chips are stored in open piles it is often desirable to unload equipment directly on the pile. A blade or scoop is usually operated by the mill to keep the pile dressed and to recover the chips. Dump trucks are capable of working directly on the pile, whereas longhaul equipment usually requires special facilities for unloading. Belt equipment can make efficient stock pile delivery with the use of a portable belt.

Pit: Truck delivery to conveyor pits that are part of other systems such as rail unloading or chip production systems are not uncommon. Dump truck and belt equipment can provide this service.

End Dump: A number of mills have installed excellent facilities for end dumping by means of an overhead hoist. Dumps of this type should be designed to accommodate trailers from 24 to 40 feet in length and require 15 tons hoisting capacity. There should be a large enough pit to receive the entire load of chips to avoid delay of the hauling equipment. This type of unloading facility requires that the hauling equipment be specialized to some degree.

Fig. 3.—Belt-trailer unloading to conveyor system.

Fig. 4.—Belt-trailer unloading to stockpile.

A hydraulically tilted ramp is another excellent method employed in end-dump unloading of chips. Most installations lift the tractor as well as the trailer, however it should be readily understood that it is necessary to tilt only the trailer for unloading. One great advantage to this system is that the hauling equipment need not be specialized for unloading. Cost of this facility is comparable to the overhead hoist type. One new mill in Washington has installed a hydraulic end dump that will unload both trucks and rail cars.

End Dump by Lift Truck: Recently developed in the Columbia River Area, unloading of double semi-trailers is being accomplished with pneumatic tired lift trucks. The trailers are 24 feet long and are hauled in tandem on the highway giving a capacity of sixteen or more 200 cubic foot units and a weight payload of 50,000 pounds. The lift trucks in use have 16,000 pounds lifting capacity to a height of 17½ feet. They are equipped with a special dumping attachment on the forks to lift and maneuver the trailers. This method provides portability for unloading at various locations and does not require an expensive fixed unloading facility.

Conveyor: Delivery direct to conveyor systems is a specialty that singles out the belt trailer. Little accommodation is required to receive chips by this method.

Loading Facilities

Wood chips are usually produced continuously one or more shifts each day. The rate of production varies due to many factors and the transportation must be flexible and efficient through a wide range of conditions. To achieve most economical usage of hauling equipment, surge capacity and fast loading is essential. The amount of storage depends on many factors but usually the longer the haul, the more important storage becomes. There are several methods for storing and loading chips.

Open Stockpile: Large volume storage at the production point can be provided at very low cost by stock piling on a paved area. Consideration must be given to prevent contamination of the chips by air-borne dirt and soot, and mud and dirt that could be tracked in by the hauling equipment. Also prolonged open storage in a wet climate would increase the weight that must be transported. It is not difficult for one man to load 13 units into a semi-trailer with a power scoop in 45 minutes. This method has the advantage of large storage capacity at low cost. Lost production due to transportation delays and hauling delays due to production breakdowns are at a minimum with this method. Also the loading equipment is completely portable.

Trailers for Bins: One of the commonest methods for storing and loading chips at the production point is the use of trailers placed under automatic or semi-automatic loaders. This method requires the shipper to assume some responsibility for the loading. The investment required for this type of storage is more costly than a fixed bin that does not have to be lightweight, or have running gear and licenses. This system does have the advantage of portability and fast turn around for the tractor equipment. Also, since the equipment is loaded while the chips are being produced, various types of conveyor systems and loading devices can be used.

Fixed Bins: There are many bins in operation today and it is probably safe to say that no two are alike. Generally speaking they are usually elevated high enough so that hauling equipment can either be driven underneath or alongside so that the chips, when released, fall into the body ; gravity. There are many variation n methods for filling the bins that pend on the choice of conveyor sys and whether or not each load mus metered. There are also many va tions in methods for transferring load to the hauling equipment.

One bin type that has been q satisfactory has bottom doors that open. This bin has one or more c partments about 12 feet wide and 6 feet long with sufficient volume o hold 14 or more units. The doors in the bottom of each compartment held closed by cables attached to counterweights and a latch assembly located at ground level. The compartments usually arranged end to end and it is desirable for the roadway under the bins to be surfaced to prevent chang in road elevation and to make it easy to recover spilled chips. The load in each compartment is regulated by mechanical or electronic metering.

The procedure followed in loading is to position the trailer or truck body under the bin and release the bin doors. The load drops and then, as the body is pulled ahead, the load spreads out and is trimmed by a screed. takes just a few seconds to load a 1 unit trailer.

There are several types of bins that control the transfer of chips from t bin to the truck body. Side doors, S feeders, live bottoms, and removab bottom boards make this control p sible. There are advantages and d advantages to each type but in th system, the driver can control t amount of the load and its distrib tion. Star-feeder and live-bottom bi load out a trailer in less than 10 mi utes but have a practical limit in si unless they are built in multiple uni They are quite expensive to build a do require maintenance. The bottor board bin is about the lowest cost bi to build and can provide large capa ity. It loads trucks slowly and requir

Fig. 5.—Bottom-door, two-compartment bin provides fast loading for truck equipment.

Fig. 6.—Sixty-unit bin with star-feeder provides large capacity and controlled loading.

considerable work for the man doing the loading. Average time to load a 15 unit trailer is 30 to 40 minutes.

Weighing: On long hauls it is very important to carry maximum payload without overloading. It has been found worthwhile to provide an axle scale adjacent to chip loading bins and a means to correct the loading to a close tolerance.

Measure: It is usually a function of the hauling to provide a measure of the chips transported, either by weight or cube. This information is vital to the producer, the carrier and the consumer in regard to purchasing the chips and the transportation.

Cost Analysis

There are many methods for estimating trucking costs. Some are based on mileage, some on time; others use a combination of time and mileage. The party that pays the bill has to know what it is going to cost, and the party that does the hauling has to make a profit. This is true, regardless of whether the operation is to be by contract, common or proprietary carriage. Ordinary rule of thumb guessing can be dangerous if applied indiscriminately to wood chip hauling; however, a careful consideration of the various elements of cost can determine with accuracy what the rate should be for any given haul.

Fixed Costs: In the operation of a truck, there are some costs that remain the same regardless of how much the truck is used. Depreciation, insurance, licenses, and interest cover most of these costs. Heavy duty equipment can usually be written off in 6 years or less. If it is assumed that the truck would operate 200 days per year, it would have operated 1200 days in 6 years. In this time $1.00 per day would amortize $1,000 and leave $200 for insurance, licenses and interest. The round figure of $1.00 per day per $1,000 invested gives realistic consideration to the fixed costs.

Therefore, a $22,000 heavy duty diesel tractor and an $8,000 40-foot semi-trailer costs $30.00 per working day to own whether you use it or not.

We are not overlooking the fact that there would be salvage in the equipment at the end of 6 years. Likewise it must be recognized that it is not possible to obtain 100 percent usage of the equipment. It is imperative to provide a reasonable use factor to properly take care of servicing and maintenance. A breakdown of hauling equipment can be very expensive if the chips go into the burner.

Variable Costs: The cost of fuel, tires, and maintenance is usually proportional to the mileage operated. Wide variations can be found in these costs depending on length of haul, type of road, efficiency of the operator, and cost of supplies, parts and labor. Long hauls on superhighways naturally result in low cost per mile. The only safe method for determining the cost per mile for these important items is to survey the route and compare with previous experience. In our operations we have noted some long hauls under ideal conditions that show these costs at less than 15¢ per mile and on one heavy volume haul of two miles through a congested area

Fig. 7.—Twenty-five unit bottom-board bin provides controlled loading for 30-mile haul.

Fig. 8.—Scoop loading from slab provides large storage capacity at low cost.

Fig. 9.—Double semi-trailer has large capacity in weight and volume turns inside 60-foot circle.

Fig. 10.—Lift truck unloads 24-foot semi-trailer. Portable unloader at low cost is provided by carrier.

the cost is greater than 60¢ per mile. Careful estimating of each item on a mileage basis can give a good indication of what the cost should be, but the estimate should provide for unexpected expenses that are bound to occur.

Labor: This is the most important item of cost. Wage rates are not hard to determine, but the actual labor cost also includes vacations, paid holidays, health and welfare plans, pension plans, payroll taxes, and overtime. For a safe estimate of labor cost, add 50 percent to the pay scale. Don't overlook possible wage increases if the program covers a number of years. Using a basic daily wage of $20.00, the estimated labor cost should be $30.00 per man per shift.

Supervision and Overhead: This item can be estimated as a percentage of revenue and although the exact percentage may vary from one operation to another, 15 percent is reasonable for estimating purposes.

Profit: This is the incentive for anyone to undertake the hauling as a contract or common carrier. For a proprietary haul it is extremely important to have a strong incentive for efficient operation and unless there is a profit, there is no advantage. A reasonable profit to strive for is 10 percent of gross revenue.

Mileage Taxes and Tolls: Some States impose a mileage tax based on gross weight. In Oregon, for example, the tax amounts to 6.2 cents per mile for 72,000 pounds gross weight. This applies to every mile operated whether looaded or empty, and is more than the cost of fuel. Bridge and ferry tolls, if they will be encountered in an operation, must not be overlooked but should not be included in the computation for supervision, overhead and profit.

Example 25 Mile and 125 Mile Hauls: Refer to Appendix A and Appendix B for a cost analysis of the hypothetical hauls.

Conclusion

It is inevitable that truck transportation of wood chips will become more and more important to the pulp and paper industry as time goes by. It is hoped that the information contained in this paper will be helpful in the establishment of reliable service where there is a need for truck hauling. Dependable common or contract carrier service can be developed by simple recognition of the profit motive and the requirement that bidders show proof that their proposal is compensatory. Attention to this principle will foster the creation of a valuable utility for people interested in the transportation of wood chips.

APPENDIX A

Example 25 Mile Haul. For purposes of illustration, let us study a hypothetical 25 mile haul. We will assume that it is possible to load in fifteen minutes or less and that it is possible to load or unload at any time of the night or day. We will compare the cost of belt delivery and end dump delivery and also compare two shift and three shift operations. We will assume that the route is on good roads and 40-foot semi-trailers may be used having a maximum gross weight of 72,000 pounds. We will also assume that there is sufficient volume of wood chips available to keep one or more pieces of equipment fully occupied. Our calculations are based on one tractor and one semi-trailer.

	2 shift Belt Delivery	3 shift Belt Delivery	2 shift End Dump Delivery	3 shift End Dump Delivery
Trips per shift	3	3	4	4
Trips per day	6	9	8	12
Miles per shift	150	150	200	200
Miles per day	300	450	400	600
Capacity per load	42,000#	42,000#	44,000#	44,000#
Capacity per day	252,000#	378,000#	352,000#	528,000#
3500# units per day	72	108	100	150
4000# units per day	63	95	88	132
Investment in Tractor	$22,000	$22,000	$22,000	$22,000
Investment in Trailer	$11,000	$11,000	$ 8,000	$ 8,000
	Daily Costs			
Depreciation, Ins. & Lic	$30.00	$30.00	$30.00	$30.00
Fuel, Tires & Maint, @ 15¢ per mile	45.00	67.50	60.00	90.00
Labor @ $30.00/shift	60.00	90.00	60.00	90.00
75%	138.00	190.50	150.00	210.00
Supervision & Overhead 15%)				
Profit 10%)	46.00	63.50	50.00	70.00
Total Daily Cost 100%	184.00	254.00	200.00	280.00
Cost per 100 pounds hauled	7.3¢	6.7¢	5.7¢	5.3¢
Cost per 3500# unit	$2.56	$2.35	$2.00	$1.86
Cost per 4000# unit	$2.92	$2.68	$2.28	$2.12

APPENDIX B

Example 125 Mile Haul. In this example we will assume 50 miles in Washington and 75 miles in Oregon all on good roads. End dump unloading is assumed to be convenient for either 40-foot semi-trailers or 24-foot semi-trailers as used in doubles. Oregon Ton-Mile Tax is 6.2¢/mile on the 40 foot and 6.8¢/mile on doubles. Loading and unloading can be done at anytime night or day and loading time is fast. It is possible to make a complete turn around in eight hours

	2 shift 40 foot Semi	3 shift 40 foot Semi	2 shift Doubles	3 shift Doubles
Trips per day	2	3	2	3
Miles per day	500	750	500	750
Capacity per load	44,000#	44,000#	48,000#	44,000#
Capacity per day	88,000#	132,000#	96,000#	144,000#
3000# units per load	14.7	14.7	16.0	14.7
3500# units per load	12.6	12.6	13.7	12.6
4000# units per load	11.0	11.0	12.0	11.0
3000# units per day	29.4	44.0	32.0	48.0
3500# units per day	25.2	37.8	27.4	41.2
4000# units per day	22.0	33.0	24.0	36.0
Investment in tractor	$22,000	$22,000	$19,000	$19,000
Investment in trailers	$8,000	$ 8,000	$11,000	$11,000
	Daily Costs			
Depreciation, Inc. & Lic	$30.00	$30.00	$30.00	$30.00
Fuel, Tires & Maint @ 14¢ per mile	70.00	105.00	70.00	105.00
Labor @ $30.00/shift	60.00	90.00	60.00	90.00
75%	160.00	225.00	160.00	225.00
Supervision & Overhead 15%)				
Profit 10%)	53.33	75.00	53.33	75.00
Total 100%	213.00	300.00	213.00	300.00
Ton Mile Tax	18.60	27.90	20.40	30.60
Total Daily Cost	231.93	327.90	233.73	330.60
Cost per 100# pounds hauled	26.4	24.8	24.4	23.0
Cost per 3000# unit	$7.92	$7.44	$7.32	$6.90
Cost per 3500# unit	$9.32	$8.68	$8.55	$8.05
Cost per 4000# unit	$10.56	$9.92	$9.76	$9.20

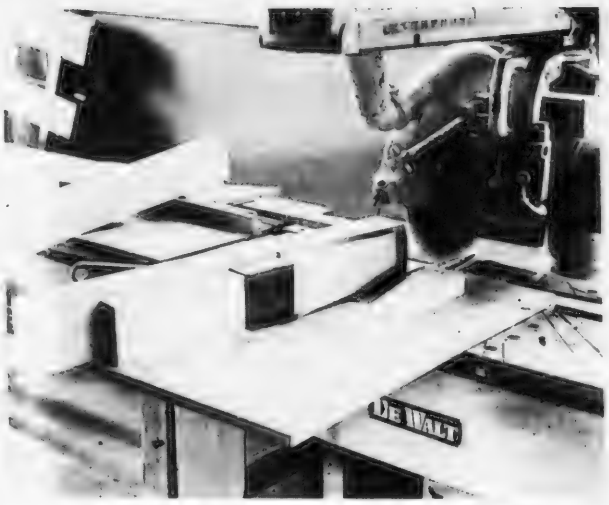


Fig. 1.—Completed scarf joint cut and holding jig.

Fig. 2.—Scarfed studs were surfaced to 1½ by 3½ inches after gluing and reconditioning.

Finger Jointing at High Moisture Content[1,2]

R. A. Currier
Forest Products Division, Oregon Forest Research Center, Corvallis, Oregon

Scarf joints and finger joints were machined in Douglas-fir lumber that ranged from 8 to 23 percent in moisture content. Effect of drying stresses was evaluated by subjecting end-glued studs to various degrees of seasoning before subjecting them to static-bending tests.

DURING THE PAST FEW YEARS, rapid advancements have occurred in the end gluing of wood products. Basic techniques for end gluing have been improved, and specialized machinery has been developed for producing end joints. At least 40 plants are operating end-gluing equipment on the Pacific Coast. Production varies from end-glued molding and window stock to end- and edge-glued panels, shelving, siding, furniture and other specialty items.

Ponderosa pine and redwood are the principal West Coast species end glued at present. These species usually are kiln-dried to MC (moisture content) of 8–12 percent, which is optimum for most wood glues. When structural-size Douglas-fir lumber is kiln dried, the final MC usually averages 15–20 percent. The upper limit of wood MC for gluing with standard wood adhesives seldom exceeds 15 percent, according to instructions of most glue manufacturers.

Under kiln-drying practices in the Douglas-fir region, wood MC has been a factor in preventing manufacture of end-glued studs. The management of a mill in Oregon made an analysis of economics involved in end gluing. This particular mill specializes in production of kiln-dried Douglas-fir studs, and addition of equipment for end gluing appeared economically practical. Technical questions unanswered, however, included the following:

- Would present commercial glues produce satisfactory end joints in Douglas-fir at 15–20 percent MC?
- What was the tolerance for variation in MC between adjacent pieces of an end-glued stud?
- If studs are end-glued at high MC, what are effects of stresses set up in the glue lines when the stud is dried to low MC?

Work reported herein resulted from research performed in an attempt to answer such questions.

Previous Work and Related Studies: Little research has been published pertaining to gluing of wood at moisture content above 15 percent. No direct reference to end gluing of wood at high MC was found.

Normal MC for gluing of wood was considered to be 6–15 percent; MC above 15 percent was considered high. The Wood Handbook (2)[3] states that glues will adhere to wood with any MC up to 15 percent, and water-resistant glues will adhere to wood at somewhat higher MC. For synthetic resin glues of the resorcinol or phenol-resorcinol type, wood MC recommended is 6–15, or 6–17 percent (7, 9, 16).

Although no reference was found pertaining to end gluing at high MC, publications were available dealing with laminating wood with moisture content as high as 50 percent. Murphey and Nearn (12) laminated red oak at MC's ranging from 1 to 50 per cent, using resorcinol glue. Laminations were dried to 5–10 percent MC and subjected to block shear tests. Results indicated wood glued at 8, 14 and 22 percent MC had shear strengths significantly higher than wood glued at 1, 4, or 50 percent.

Olson (13) laminated wood at 6 to 21 percent MC and pressed plywood from veneer at 2 to 25 percent MC. The 13 resin glues studied in-

The Author: R. A. Currier received his B.S. degree in forestry from the University of Massachusetts and his M.S. in forest utilization from New York State College of Forestry. He has been a wood technologist at the Center since 1952.

[1] Presented at Session IV, Glues and Gluing, FPRS 13th National Meeting, June 29, 1959, in San Francisco; revised copy received by the Journal May 16, 1960.

[2] The following organizations provided materials and/or assistance for this study: Sun Studs, Inc., Roseburg, Oreg., Koppers Co., Inc., Pittsburgh, Pa., Monsanto Chemical Co., Seattle, Wash., and Weyerhaeuser Co., Longview, Wash.

[3] Numbers in parentheses refer to literature cited.

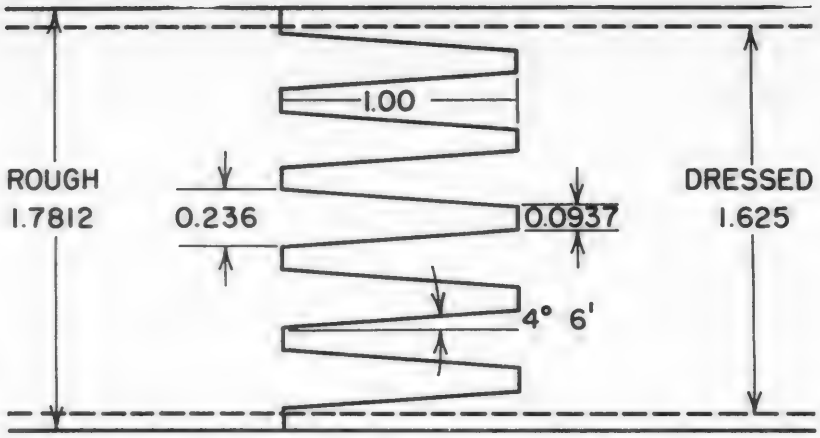


Fig. 4.—Edge view of finger—joint pattern. Dimensions are in inches.

cluded phenolics, melamines, and resorcinols. Acceptable bonds were found in both laminated wood and plywood glued at high MC. Certain glues appeared to tolerate high MC better than did other glues of the same type.

Finnorn (5) determined effects of various open and closed assembly times when laminating red oak at 29–35 percent MC with a phenol-resorcinol glue. After laminating, specimens were conditioned to 10 percent MC and subjected to block-shear tests. Shear strength averaged 2518 psi with 85 percent wood failure. Other specimens went through a delamination test without failure; tests of residual strength showed 92 percent wood failure at 2888 psi.

Many writers warned that gluing wood at high MC should be avoided if the finished product will be used under dry conditions. Shrinkage stresses may result, seriously weakening wood and glue joints (2, 3, 5, 7, 9, 13, 16). However, Murphey and Nearn stated the magnitude of stresses resulting from changes in wood MC from that at time of gluing cannot be the entire cause of glue-bond failure (12).

Uniformity of MC between adjacent pieces of wood to be end-jointed presents an additional gluing factor. Widely differing MC at time of gluing may lead to uneven wood shrinkage with subsequent glue-line stress. The U. S. Forest Products Laboratory states the range in MC between pieces in a single assembly should not exceed 5 percent (7). This tolerance also is recommended by the Forest Products Laboratories of Canada (9).

When wood is glued at high MC, excessive penetration of glue often results in starved or "washed out" joints. Excess of water in the wood causes glue to migrate rapidly from the glue-line area (3, 12, 16).

Since end joints usually expose a large proportion of end grain, control of glue penetration becomes a critical factor, even at MC considered normal. Double spreading glue, coupled with increased open assembly times, will assist in controlling penetration (7, 14, 15). According to Richards (15), need exists for formulation of special glues to control excessive penetration into end grain.

A report by Erickson (4) gives results of strength tests performed on finger-jointed Douglas fir studs. Average efficiency in edgewise bending was 59 percent, expressed as a percentage of the strength of clear wood adjacent to the finger joints. A basic study by Luxford and Krone (10) compared strengths in tension and compression of various types of end joints, including both scarf and finger joints.

The literature survey also revealed notes of caution concerning research procedures involved in studying end gluing. If joints are fabricated from matched pieces (cutting a piece of wood in two, machining an end joint, and regluing), there is danger of obtaining joints having strengths higher than those from pieces of wood end-glued at random (6, 7, 8, 15).

Important basic research on end gluing has been reported by Marian, Stumbo, and Maxey (11). Small specimens of Douglas-fir were end-glued with 1:1 scarf and butt joints. The authors concluded that the basic problem in end gluing is to eliminate reduction in strength caused by contact of springwood with summerwood.

A recent amendment to the Western Pine Association grading rules covers laminated studs (1). Provision has been made for inclusion of either scarf or finger joints. Spacing of end joints is prescribed, and slope of scarf or fingers must not exceed 1:7.

Scarf Joints

Scarf-jointed Douglas-fir studs were fabricated and tested before finger joints were tested. Scarf joints expose

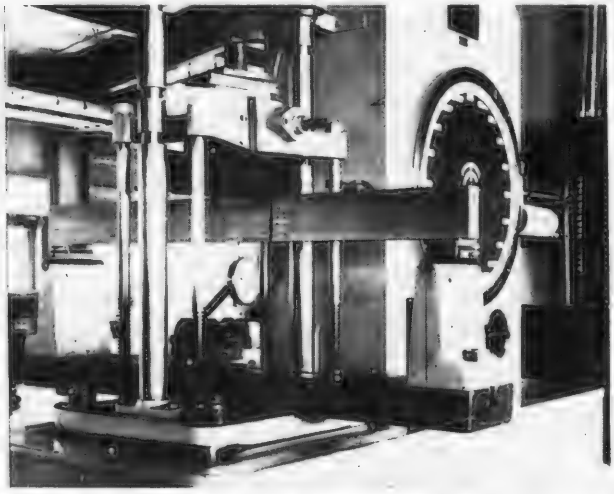


Fig. 3.—Bending test of scarf-jointed stud. Stud is on edge with load applied at the center.

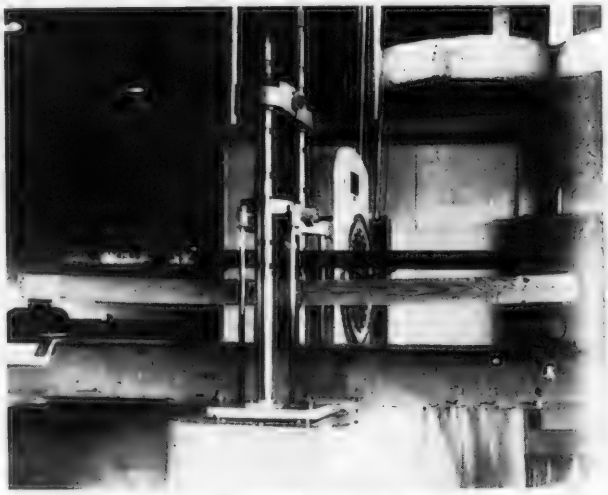


Fig. 5.—Bending test of finger-jointed stud. Stud is on edge with load applied at third points.

Table 1. Strength and Stiffness of 1 1/2- by 3 1/2-Inch Douglas-Fir 1:6 Scarf Joints Glued With Phenol-Resorcinol Glue and Tested at Various Moisture Contents.

...ture content			Modulus of rupture			Modulus of elasticity		
...ing		At test	At test	Corrected to 12% MC	Efficiency*	At test	Corrected to 12% MC	Efficiency*
		%	Psi	Psi	%	M Psi	M Psi	%
		20.9	7,170**	10,200	84	1,168	1,560	67
		16.6	9,090	10,910	89	1,252	1,660	76
		10.2	11,000	10,240	84	1,409	1,364	70
	4	16.0	8,460	[illegible]	85	1,160	1,247	64
	4	9.5	11,440	[illegible]	88	1,441	1,576	71
		9.5	10,670	9,665	79	1,320	1,262	65
	4	14.7	9,360	10,415	85	1,229	1,240	66
	4	9.8	11,340	10,395	85	1,461	1,404	72
		9.0	10,330	9,170	75	1,365	1,293	66
		8.7	10,250	8,990	74	1,362	1,284	66
		----	9,910	10,025	82	1,311	1,318	68

*Based on dividing test values corrected to 12% MC by those listed in U.S.D.A. Publication No. 72 for Douglas-fir at 12% MC.

**Each value is the average of 10 specimens subjected to bending on edge under center loading.

Fig. 6.—Typical scarf joints after bending test. From left to right, 20 to 20, 20 to 14, and 20 to 8 percent MC at time of gluing. All joints subjected to EMC conditions of 8 percent prior to test.

end grain similar in nature to finger joints and could be made with available laboratory equipment. Results of tests performed on scarfs led to elimination of non-critical factors in the finger jointing phase of research.

Experimental Procedure: Kiln-dried, S4S, old-growth Douglas-fir studs were obtained with MC ranging from 12 to 27 percent, and averaging 18 percent. The 8–foot studs were cross-cut to produce 25–inch lengths free of defects. Where more than one 25–inch piece could be obtained from an 8–foot stud, suitable coding marks were applied to indicate the pieces originated from the same stud. This procedure eliminated the possibility of regluing two pieces from a single stud.

Studs cut to 25–inch lengths were placed at random into 3 groups. One group was conditioned in an atmosphere of 90 percent RH (relative humidity) at 90° F., another group was conditioned at 75 percent RH at 90° F., and the remaining group was conditioned at 44 percent RH at 90° F.; EMC (equilibrium moisture content) conditions of 20, 14, and 8 percent, respectively.

When studs had reached desired MC, they were surfaced to 1 9/16 by 3 9/16 inches just prior to cutting and gluing scarf joints. For cutting scarf joints, a jig was bolted to the table of a radial arm saw, and a stud was inserted on edge into an adjustable collar. The collar was tightened, thus holding the stud securely in place. As the saw was pulled forward, a scarf joint having a slope of 1:6 was cut. A planer-type saw blade produced a well-cut scarf joint (Figure 1).

Studs were scarf-glued according to 10 different combinations of MC at time of pressing and degree of drying after gluing (Table 1). For each of the 10 combinations, 10 scarf joints were prepared for a total of 100 specimens.

Scarf faces were double-spread with phenol-resorcinol glue at an average rate of 80 pounds of glue to 1000 square feet of joint area. Studs glued at MC of 8 or 14 percent were permitted an open assembly time of 5 minutes. Where a joint involved one or both members at 20 percent MC, open assembly time was increased to a maximum of 10 minutes. Lengthened assembly time increased degree of glue tackiness, thus decreasing the possibility of excessive penetration into the damp wood when pressure was applied.

After completion of open assembly time, each pair of pieces was assembled and placed between the platens of a 2-foot-square hot press. Scarf joints were pressed singly at 220° F. for 15 minutes. Under these pressing conditions, the center of the glue line reached 140°–150° F.

After gluing, scarf joints were placed in the proper EMC conditions to obtain desired MC at time of test (Table 1). Dry-bulb temperature for 14 percent EMC was lowered from 90° F. to 70° F.

Reconditioned scarfed studs were planed lightly on all four sides to remove glue from the surface (Figure 2). Final dimensions averaged 1½ by 3½ inches. The 40–inch specimens were placed on edge over a 36–inch span with the center of the scarf joint positioned in the center of the span (Figure 3). Studs were loaded in the center at a headspeed of 0.1 inch a minute. Ratio of span to depth was 10.3. Deflections at the neutral axis were plotted up to a load of 1500 pounds, and ultimate failing load was recorded. Moisture content at time of test was determined from wafers cut from each end of the scarf joint.

Moduli of rupture and elasticity (MOR and MOE) were calculated directly from test data, and also for a base MC of 12 percent. Strength values were adjusted to the common moisture basis by procedures outlined in the *Wood Handbook* (2). Efficiencies of the scarf joints were obtained by dividing strength values, corrected to 12 percent MC, by those listed for solid Douglas-fir at a similar MC (2).

Results and Discussion: Results of bending tests performed on scarf-jointed studs are presented in Table 1. All comparisons are based on strength values corrected to 12 percent MC. The average MOR of 10,025 psi and efficiency of 82 percent for all 10 combinations of MC at time of gluing and at test was very good, considering the relatively steep scarf slope of 1:6. Efficiency was based upon the published value of 12,200 psi for Douglas-fir at 12 percent MC (2).

No adverse effect upon MOR was apparent when scarf-jointed studs glued at high MC were dried to lower MC prior to bending tests. Studs scarf-jointed at 20 percent MC and tested at 20.9, 16.6, and 10.2 percent MC had moduli of rupture averaging 10,200, 10,910, and 10,240 psi, respectively. The series of studs glued with one end at 20 and the other at 14 percent MC reacted similarly, since bending strength when tested at MC of 16.0 and 9.5 percent was 9,910 and 10,360 psi, respectively. For studs scarfed at 14 percent and tested at 14.7 and 9.8 percent MC, average MOR varied only 20 psi.

The 3 lowest values for MOR occurred where one or both ends of the scarf joint were glued at 8 percent MC. This MC is the minimum recommended by the manufacturer of the phenol-resorcinol glue used for scarfing, and the glue may have been affected more by low than by high MC.

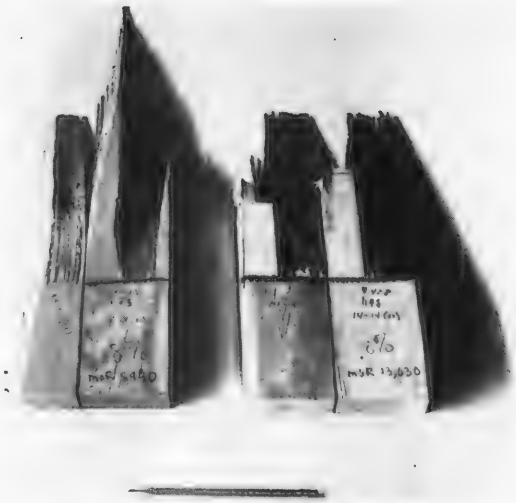


Fig. 7.—Scarf joints glued at 14 percent and dried to 8 percent MC prior to test. Left, heavy wood failure, low MOR; Right, slight wood failure, high MOR.

Fig. 8.—Typical failures in scarf joints from studs glued at 14 8 percent MC. Note springwood rupture in joint at right.

Scarf joints glued from lumber at 20 percent and tested at either 20.9, 16.6 or 10.2 percent MC exhibited very slight or no wood failure (Figure 6). In spite of low wood failure, this series produced individual scarf joints possessing remarkable bending strength. Studs scarfed with one end at 20 and the other end at either 14 or 8 percent MC showed more wood failure than did studs scarfed with both ends at 20 percent MC; the most wood failure occurred in the group glued at 20 and 8 percent MC (Figure 6).

Two joints scarfed at 14 percent and tested at 8 percent MC are shown in Figure 7. Wood failure was heavy in one specimen, and the MOR was 8990 psi; the other specimen had only slight wood failure, but the MOR was 13,030 psi.

Typical scarf joints glued at MC combinations of 14 to 8 and 8 to 8 percent may be seen in Figure 8. Breaks generally were accompanied by percentages of wood failure larger than with studs glued at 20 percent MC.

Wood failure in scarf joints resulted from rupture of springwood; no joint was noted where substantial wood failure occurred in summerwood. An excellent example of failure in springwood may be seen in Figure 8.

Average MOE for all scarfed studs was 1,318,000 psi. Efficiency averaged 68 percent, based upon the published value of 1,950,000 psi for solid Douglas-fir at 12 percent MC (2). Seasoning to low MC prior to testing increased MOE 5 to 10 percent when compared to similar studs tested without seasoning. The comparatively low values for MOE were believed caused by center-loading the scarf joints.

Scarf joints were tested only as a preliminary means of screening combinations of moisture content to be chosen for finger joints; the tests were not designed to develop basic data on strength of scarf joints.

Finger Joints

Finger-jointed studs are difficult to produce on a laboratory basis, as specialized machinery is required. Therefore all finger-jointed studs were prepared by a company that has been end gluing wood for several years, and has equipment necessary for finger jointing.

Studs conditioned to a predetermined MC prior to gluing theoretically would have equal distribution of moisture throughout. No MC gradient would be present between shell and core. If a mill were to finger-joint studs, however, this type of moisture distribution normally would not occur. Kiln-dried dimension lumber would be the raw material, and a MC gradient would be present within each piece. Therefore, in addition to finger-jointing lumber conditioned to constant MC, a second group was finger-jointed from unconditioned kiln-dried stock.

Results of tests on scarf joints indicated the number of combinations of MC at time of gluing and degree of drying after gluing could be reduced from 10 to 5. Only combinations considered most severe were included in tests of finger-jointed studs conditioned to 20, 14, or 8 percent MC (Table 2). Contrasted to the scarf-jointing experiments, the number of specimens prepared within each group was increased to 20 from 10.

Experimental Procedure: Material for finger jointing conditioned lumber was kiln-dried, old-growth Douglas-fir cut rough at a full 2- by 4-inch size. Moisture content averaged 19 percent, with a range of 17 to 31 percent. The 8-foot studs were cross-cut to lengths of 42 inches. Defects were allowed only within 8 inches from one end of the piece. Where two 42-inch lengths could be obtained from an 8-foot piece, coding marks similar to those used in the scarf-jointing tests prevented subsequent regluing of 2 cuttings from the same stud.

Moisture content of each piece was determined with a moisture meter. Pieces with the highest MC were placed in the atmosphere maintained at 20 percent EMC conditions; those with lowest MC were subjected to EMC conditions of 14 or 8 percent. When conditioned, the pieces were rough-blanked 4 sides to 1⅞ by 3½ inches. By random selection, studs with the proper MC were grouped in pairs and marked with suitable code numbers placed on the defect-free ends. Twenty pair of studs were prepared for each of the five combinations of MC (Table 2).

Four days prior to finger jointing, a second batch of rough, freshly kiln-dried studs was obtained. The same procedure used in preparing the first batch of material for finger jointing was followed in cross-cutting, rough-blanking, and determining MC.

Three groups of 20 pairs of 42-inch studs were chosen at random and marked A, B, or C (Table 3). Moisture content averaged 20 percent, with a range of 14–23 percent. Two additional groups of 20 pairs of studs also were chosen at random and marked D and E. Since these 2 groups were to be glued by radio frequency (R.F.), MC was limited to a maximum of

Table 2. Average Strength, Stiffness, and Specific Gravity of 2- by 4-Inch Douglas-Fir Finger-Jointed With Phenol-Resorcinol Glue and Tested at Various Moisture Contents. Lumber Conditioned to Constant Moisture Content Prior to Finger Jointing

Moisture content		Number acceptable	Modulus of rupture			Modulus of elasticity			Specific
	Actual			Corrected to 12% MC			Corrected to 12% MC		
	%		Psi	Psi	%	M.P.s.	M.P.s.	%	
20	20.7	20	6980	8470	69	1675	1964	101	0.54
20	9.6	19	6330	6360	52	2043	1955	100	.55
14	9.7	20	7010	6670	55	2054	1951	100	.54
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	8.8	17	7820	6890	56	1401	1798	92	[illegible]
Average	----	----	7250	7010	57	1910	1896	97	0.54

[1] Based on dividing test values corrected to 12% MC by those listed in U.S.D.A. Publication No. 72 for Douglas-fir at 12% MC.

[2] Based on oven-dry weight and volume.

percent. Average MC for groups D and E was about 18 percent, with a range of 14–21 percent.

A five-fingered joint was cut on commercial end-jointing machines (Figure 4). To cut finger joints on the 1⅞-inch-thick studs, an additional finger was added to the four-fingered joint usually cut by the cooperating company.

All finger joints from conditioned lumber and groups, A, B, and C of unconditioned lumber were double-spread with a phenol-resorcinol glue. Groups D and E, glued by RF, were spread with melamine-urea glue. Actual amount of glue spread on a joint was not measured. Open assembly time varied between 2 and 6 minutes.

Joints spread with phenol-resorcinol glue were assembled and cured in a press. Air-operated rams provided endwise pressure as the studs rested flatwise upon a steel-topped table heated by internal steam coils. Near the outfeed end of the press, additional heat was provided top faces of the studs by electrical resistance heating units suspended above the table.

Finger joints in groups D and E, spread with melamine-urea glue, were cured in a RF end-gluing press. No trouble was experienced with arcing or other malfunctions in finger-jointing the unconditioned studs at MC of 14–21 percent.

Finger-jointed pieces, now about 80 inches in length with 1 centrally located finger joint, were returned to the Research Center for reconditioning prior to testing. Four of the 5 groups of 20 each studs finger-jointed from conditioned lumber were reconditioned at EMC conditions of 8 percent; the remaining group was reconditioned at 20 percent EMC conditions (Table 2).

Of the studs finger-jointed from mill-run unconditioned kiln-dried lumber, groups A and D were tested without reconditioning after gluing; groups B and E were conditioned at EMC conditions of 8 percent prior to testing (Table 3). Group C was subjected to 5 cycles of alternate high and low RH. A cycle consisted of exposure for a week to 90 percent RH at 90° F. (EMC conditions of 20 percent) followed by 1 week at 44 percent RH at 90° F. (EMC conditions of 8 percent).

When the finger-jointed studs had reached desired MC, they were surfaced 4 sides to standard stud size of 1⅝ by 3⅝ inches (Figure 4). Only a few pieces would not surface out at these dimensions and had to be surfaced slightly under standard stud size. Because of gaps ⅛ inch or greater in the finger joint, 14 studs glued in the steam press were discarded. Undoubtedly, the gaps resulted from lack of end pressure, because, at times, rams to apply endwise pressure did not operate properly.

Finger-jointed studs were placed on edge over a 75-inch span with the finger joint in the center of the span. Third-point loading was applied, giving a ratio of span to depth of 13.8 (Figure 5). In all instances, the middle third of the span consisted of clear wood with a centrally located finger joint. Head speed of the testing machine was 0.35 inch a minute. Load at a midspan deflection of 0.3 inch was recorded, in addition to maximum load. Moduli of rupture and elasticity were calculated from test data and also for a MC of 12 percent, by the same procedure as for scarf joints.

Moisture content at test was determined from wafers cut close to the joint. Specific gravity, based on oven-dry weight and volume, also was determined from the wafers.

Correcting values for MOR and MOE to a moisture content of 12 percent, as outlined in the *Wood Handbook* (2), primarily was done to facilitate comparison among joints tested, rather than with tests of other joints, or with standard tests of solid Douglas-fir.

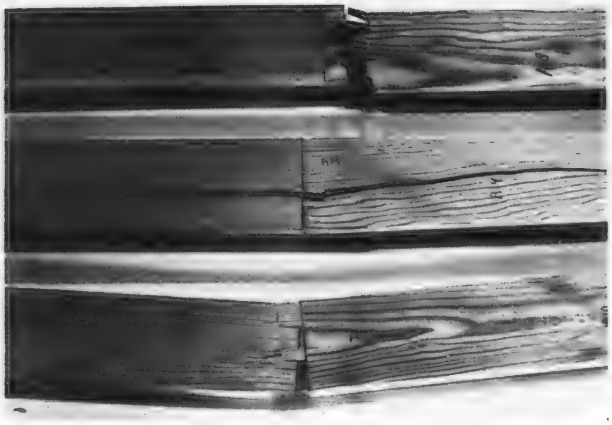
Results and Discussion: Results of bending tests performed on kiln-dried stock conditioned and unconditioned prior to finger jointing are presented in Tables 2 and 3, respectively. Contrary to results from tests of scarf joints, MOR (corrected to 12 percent MC) was reduced when studs finger-jointed at high MC were dried to low MC before testing. Studs glued from lumber conditioned at 20 percent, but tested at 9.6 percent MC, suffered a loss of 25 percent in MOR when compared to a similar group tested at 20.7 percent MC (Table 2).

Similar losses in strength were noted for finger joints in unconditioned lumber, whether glued with phenol-resorcinol on the steam-heated press, or glued with melamine-urea on the press heated with radio-frequency electricity (Table 3). Comparison of groups A and B (phenol-resorcinol glue) indicated a reduction in strength of 19 percent for finger-jointed studs dried to a low MC prior to testing. Comparing groups D and E (melamine-urea glue), MOR was 28 percent less when tested at 9.5 percent MC than were similar joints tested at 18.3 percent MC.

Certainly, losses in strength resulting from drying finger-jointed lumber to low MC before testing were not due to differences in specific gravity. Average specific gravity of groups A, B, D, and E was identical (Table 3); variation in specific gravity was slight in the two groups of studs glued from lumber conditioned to 20 percent MC (Table 2).

External manifestations of stresses caused by drying stock finger-jointed at high MC rarely were noted. An occasional check developed, but in no instance was checking considered serious enough to impair joint strength. A few studs developed slight distortion such as bowing or twisting. Drying after gluing could have resulted in stresses in glue lines of a nature that could not be assessed visually. Typical failures in bending for finger joints tested at high MC are shown in Figure 9, and Figure 10 shows failures of joints dried to low MC before being subjected to bending test.

Studs finger-jointed from conditioned Douglas-fir with one end at 20 percent and the other end at 14 or 8 percent MC had only slight variation in MOR corrected to 12 percent MC (Table 2). When compared to studs glued at 8 percent MC, maximum difference in average MOR was only 250 psi. Again, note that MC of 8 percent is the minimum recommended by the manufacturer of the phenol-resorcinol glue. Also, average specific gravity of studs glued with both ends at 8 percent MC was somewhat lower



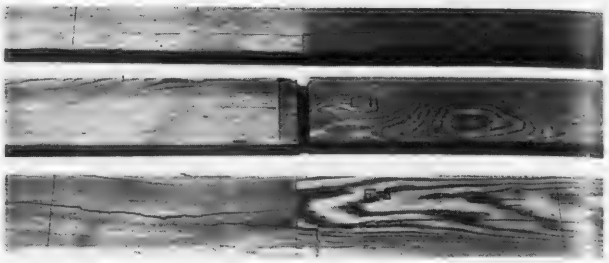


Fig. 9.—Typical failure patterns for finger joints from unconditioned kiln-dried Douglas-fir glued with phenol-resorcinol at 15 to 22 percent MC and tested at 19 percent MC.

Fig. 10.—Typical failure patterns for finger joints from unconditioned kiln-dried Douglas-fir glued with melamine-urea at 14 to 21 percent MC and tested at 9.5 percent MC.

than specific gravity of other groups of unconditioned lumber.

Group C studs, prepared from unconditioned, kiln-dried lumber and subjected to 5 cycles of alternate high-to-low RH, had average MOR greater than that of similar studs dried to low MC prior to test. The MC at test indicated studs in group C probably never went below 13 percent during cycling (Table 3).

Many finger joints glued on the steam press showed a break pattern typified in Figure 11. The outer finger of one face would be well bonded, while the opposite outer finger would fail mostly within the glue line. To point up the reversed pattern of joint failure, Figure 12 shows the same specimens as in Figure 11 turned 180 degrees. Poor joints on one face probably were caused by timing of heat application to the top face of the studs during hot pressing. The overhead heating units were located near the outfeed end of the steam press. Thus, glue spread on the uppermost fingers had additional time to penetrate before heat was applied, compared to the lower fingers which contacted the steam-heated table soon after initiation of the press cycle. The result was typical starved joints within the upper fingers.

In spite of reductions in bending strength that occurred when stock finger-jointed at high MC was seasoned to low MC, results compared favorably with bending tests performed previously at the Research Center on seasoned Construction and Standard grades of Douglas-fir 2- by 4-inch lumber (17). About 40 studs for each grade were tested in static bending under third-point loading; MC at time of test was 12 percent. Average MOR of Construction and Standard grade studs was 6265 and 4705 psi, respectively. The average MOR was 7010 psi for studs end-glued from conditioned material and 7510 psi for studs end-glued from unconditioned lumber. Bending strengths quoted for non-jointed commercial Douglas-fir studs were based on a limited number of test specimens, although the material was collected from various mills in western Oregon, Washington, and California.

Average MOE for all groups of finger-jointed studs was excellent, usually equaling or exceeding the published value of 1,950,000 psi for clear Douglas-fir at 12 percent MC (Tables 2 and 3). For studs finger-jointed from conditioned lumber, average MOE was 1,896,000 psi; for unconditioned lumber, the average was 2,115,000 psi.

Values for strength of joints tested no doubt were influenced by high density of the test material. Specific gravity averaged 0.53 for conditioned and 0.56 for unconditioned lumber tested, based on oven-dry weight and volume. These values contrast with the published value of 0.51.

Similar to MOR, the highest MOE occurred in studs finger-jointed and tested at high MC. Seasoning the finger-jointed lumber prior to bending tests resulted in decreased MOE. However, maximum loss of stiffness due to drying was only about 8 percent compared to the maximum loss of 28 percent found for MOR.

Conclusions

Based on static bending tests of scarf- and finger-jointed Douglas fir studs, the following conclusions appeared justified:

1. Douglas-fir studs with 1:6 scarf joints glued with combinations of 20 and 14 percent MC appeared to suffer no loss in MOR as a result of seasoning to low MC prior to static-bending tests.

2. Average MOE for scarfed studs was lower than expected. Center load-

Table . Average Strength, Stiffness, and Specific Gravity of Douglas-Fir Finger-Jointed and Tested at Various Moisture Contents. Lumber Kiln-Dried, But Not Conditioned

Group	Type of glue	Number of pieces	Moisture content, Range	Moisture content, Average	Modulus of rupture, MC	Modulus of rupture, PSI	Modulus of elasticity, MC	Modulus of elasticity, M.P.S.		
A	PRF									
B	PRF	58	14-24	17.9	7650	7040	58	2117	2039	105	.56
C	PRF	54	14-22	13.0	6970	7250	50	2009	2107	108	.56
D	MUF										
E	MUF										
Average							62	2043		108	.56

* Based on dividing values corrected to 12% MC by [illegible] as given in U.S.D.A. Technical Bulletin No. 72 for Douglas-fir at 12% MC.

** PRF - Phenol-resorcinol-formaldehyde; cured by steam press.
MUF - Melamine-urea-formaldehyde; cured by RF press

*** Based on oven-dry weight and volume.

Fig. 11.—Finger joints from conditioned kiln-dried studs glued at 20 and tested at 9.6 percent MC. Outer finger of top joint well bonded; lower joint poorly bonded outer finger.

ing the test pieces possibly had an influence upon MOE.

3. Studs finger-jointed from either conditioned or unconditioned kiln-dried pieces suffered loss in MOR ranging from 19 to 28 percent when seasoned at high MC and seasoned to low MC before testing. Reduction in bending strength occurred in lumber finger-jointed with phenol-resorcinol glue cured by a hot press, and in lumber finger-jointed with melamine-urea glue cured by RF.

4. Average MOR for finger-jointed studs compared favorably with average bending strength of Construction and Standard grades of Douglas-fir 2-by 4-inch dimension lumber as determined by limited previous research.

5. For the majority of finger-jointed pieces, MOE exceeded the traditional average for clear Douglas-fir. Drying finger joints after gluing lowered MOE, but the degree was slight compared to reduction in MOR.

6. No visible defects of a serious nature were noted as a result of seasoning finger joints to low MC after gluing.

7. Direct comparisons between scarf and finger joints should be made with caution, due to different methods of performing bending tests.

8. Finger-jointed studs possessing strength adequate for many uses can be made from clear lengths of kiln-dried Douglas-fir at MC of 14–20 percent.

Literature Cited

1. Anon. 1956. Laminated products certification. Western Pine Assn., Portland, Ore.
2. Anon. 1955. Wood Handbook. Handbook No. 72, U. S. Dept. of Agri.
3. Bergin, E. G. 1948. Effect of wood moisture content of gluing. No. 137, For. Prod. Labs. of Canada, Ottawa, Ontario.
4. Erickson, E. C. O. 1955. Strength tests of spliced studs. Rep. No. 1275, U. S. For. Prod. Lab., Madison, Wis.
5. Finnorn, W. J. 1956. Gluing untreated red oak at fiber saturation point. Wood and Wood Prod. 61(12), 22–23, 48–52.
6. Fox, S. P. 1956. An invertigation into the effects of certain variables in scarf-jointed timber laminations. For. Prod. Jour. 6(10), 428–437.
7. Freas, A. D. and Selbo, M. L. 1954. Fabrication and design of glued laminated wood structural members. Tech. Bull. No. 1069, U. S. Dept. of Agri.
8. Jessome, A. P. 1956. The efficiency of scarf joints. Canadian Woodworker.
9. Kennedy, D. E. 1951. Canadian Woods. For. Prod. Labs. of Canada. Ottawa.
10. Luxford, R. F. and Krone, R. H. 1953. End joints of various types in Douglas-fir and white oak compared for strength. Rep. No. 1622, U. S. For. Prod. Lab., Madison, Wis.
11. Marian, J. E., Stumbo, D. A. and Maxey, C. W. 1958. Surface texture of wood as related to glue-joint strength. For. Prod. Jour., 8(12), 345–351.
12. Murphey, W. K. and Nearn, W. T. 1956. Effect of moisture content on the performance and appearance of resorcinol glue lines in laminated oak lumber. For. Prod. Jour. 6(5), 194–197.
13. Olson, W. Z. 1954. Effect of moisture content of wood on joint strength in gluing birch veneer and maple lumber with room-temperature-setting and intermediate-temperature-setting phenol, resorcinol, and melamine glues. Rep. No. 1534, U. S. For. Prod. Lab., Madison, Wis.
14. Olson, W. Z. and Bruce, H. D. 1955. Strength of joints in hard maple blocks, glued with certain resin glues, after various open and closed assembly periods. Rep. No. 1542, U. S. For. Prod. Lab., Madison, Wis.
15. Richards, D. B. 1958. End gluing lumber. For. Prod. Jour. 8(3), 99–104.
16. Smith, N. F. 1955. Adhesives in glued laminated timber construction. For. Prod. Jour., 5(3), 168–174.
17. Snodgrass, J. D. 1959. Statistical approach to working stresses for lumber. ASCE Proceedings. 85 (ST 2).

Fig. 12.—Finger joints in Figure 11 turned 180 degrees to show reversed pattern of joint failure.

Marketing Wood Residues from Small Sawmills[1]

MILTON APPLEFIELD

Associate Wood Technologist, Forest Products Department, Texas Forest Service, Lufkin, Texas

The opportunity for greater utilization and profit from each sawlog has been overlooked by many pine sawmill operators in East Texas. At a mill with a daily average production of 10,000 board feet of southern yellow pine lumber, the use of slabs, edgings and trims as raw material for pulp chips can increase profits by as much as $35.00 per day. Low cost equipment and techniques have been developed, and a stable chip market is generally available for the small mill operator in East Texas.

The production and sale of pulp chips are usually more profitable than the production and sale of unbarked or bark-free residues. Also, the yield of bark-free chippable residues, per thousand board feet of given log size, is greater when a log barker is employed to remove the bark than when a slab debarker is used to debark the slabs, edgings and trims. As a result, log debarking followed by lumber sawing and residue chipping appears to be the most profitable method of utilization for the small mill operation. Based on a mill with a daily production of 10 MBF of pine lumber and an equipment investment within the range of $3,500 to $23,000 the following conclusions are justified.

1. Depending on the method of residue utilization employed and market availability, sawmills and with a minimum daily lumber production of as low as 7 MBF can realize a profit from their mill residues.

2. Burning or piling mill residues is an expense. The cost can be applied to the purchase of residue utilization equipment. An investigation of the amount and kind of residue available, the specific equipment and techniques suitable, and a reliable estimate of the sale potential will provide the factual background for deciding on the desirability of a residue utilization program.

3. The greatest return from sawmill residue utilization, per thousand board feet of lumber, is realized through debarking the logs *prior to sawing*, and then chipping the resulting bark-free slabs, edgings and trims.

4. Some profit can often be realized from the sale of unbarked residues, or bark-free residues, debarked by a round log debarker. Although such utilization requires the least capital investment, neither sales nor profit potential is as great as when the residues are processed and sold as chips.

5. The sale of bark-free slabs, edgings and trims, debarked with a slab-debarker, does not appear to be profitable for a sawmill which produces less than 11.2 MBF lumber per day.

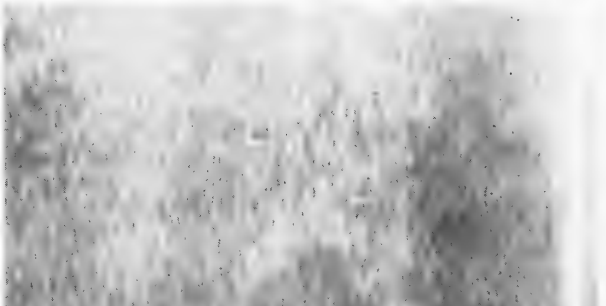
6. A concentration yard, employing a slab barker and chipper, and producing chips entirely from unbarked, purchased residues would likely be an unprofitable operation. However, there are opportunities for the sale of such residues to existing installations with excess production capacity for processing residues.

[1] A condensation of a paper presented at the October 1959 Midsouth Section Meeting in Beaumont, Texas, and received by the Journal May 2, 1960. The complete paper entitled "The Production and Marketing of Pine Wood Residues by Small Sawmills," is available from the Texas Forest Service as Bulletin 50, dated March 1960.

THE POTENTIAL OF . . .

Western Hardwoods for Veneer and Plywood

A panel faced with madrone veneer. The face veneer was flat-sliced and book-matched.



A panel faced with rotary-cut veneer of tanoak.

PETER H. KOEHLER
Coastal Veneers, Inc., Crescent City, California

The potential of western hardwoods has barely been tapped. Forest Service estimates show 23 billion feet of merchantable logs on the Pacific Coast. If carefully produced and properly promoted, these woods should make valuable and attractive additions to the domestic veneer and plywood market.

FOR THE MOST PART, western hardwoods have met with little success in the domestic veneer and plywood field. This has not been the fault of the species themselves, but rather the result of a number of circumstances. In the first place, several marginal operations have attempted to utilize these woods without sufficient capital to launch and promote them properly. Secondly, and more important, a few Douglas-fir plywood plants have experimented with western hardwoods and come up with adverse results. Most of these mills were engineered for the specific purpose of peeling Douglas-fir as swiftly and efficiently as possible, and they were not set up to handle hardwoods from the standpoint of quality. Consequently, the western species received a "black eye" from these experiences. Western hardwoods are as difficult, if not more difficult, to manufacture into veneer than are their Eastern counterparts, and they should be handled with hardwood machinery and hardwood know-how.

There has been some success with these woods in the veneer and plywood field. A peeler plant in Kelso, Washington specialized in western maple veneers for radio cabinets more than 20 years ago. Coastal Veneers, formerly Timberline Inc., Crescent City, California, has been working with western veneers for the past few years. In addition, several of these species have been exported for many years to the European market in the log form for remanufacture into veneer.

There are no exact cruises available giving the board footage volumes of the various Western species. However, recent estimates from the U. S. Forest Service, California Forest and Range Experiment Station, Berkeley, California indicated there are 23 billion feet of merchantable hardwood logs on the Pacific Coast. The largest concentrations of these trees grow in Southern Oregon and Northern California. The following tabulation shows volumes by species in millions of board feet:

Species	Calif.	Ore.	Wash.	Total
Red Alder	150	3900	5100	9150
Black Cottonwood	----	----	1000	1000
Pacific Madrone	800	800	----	1600
Oregon Maple	----	1500	1800	3300
California Black Oak	1000	500	----	1500
Tanoak	2000	1700	----	3700
Others	1150	600	100	1850
				23600

These figures show there is an ample supply of raw materials, even after taking into consideration the fact that only a small percentage of these logs can be used for veneering purposes.

Logging Methods

Generally the better stands of these woods grow on the fringe areas of redwood or Douglas-fir forests. The trees grow in small individual stands or intermixed with the conifers. For the most part, the hardwoods are troublesome for the large redwood or Douglas-fir logger. In the first place they are in the way and are usually knocked down in the harvesting of the larger conifers. They also present slash problems and limit reseeding operations. Probably the best method of handling these hardwoods when they are intermixed is to harvest the

The Author: Peter H. Koehler holds a degree in economics from Stanford University. He is vice-president and general manager of Coastal Veneers, Inc.

[1] Presented at Session II, Veneer and Plywood, FPRS 13th National Meeting, June 1959 in San Francisco.

hardwoods on a pre-logging or post-logging program. This would enable the redwood or Douglas-fir operator to rid himself of the troublesome hardwoods, and it would provide the hardwood mill with its necessary raw material. Where the hardwoods grow in accessible pure stands or on farm or open lands, there is no problem.

One of the most disturbing problems in the harvesting of the western hardwoods today is the lack of utilization of the lower grade trees. With the exception of the export market, the only use for these species is the veneer market, which means that only the best trees can be used. Consequently, the logger's costs are higher because he can only harvest a few trees from a given stand. Also, the stumpage owner is unhappy because he feels that he is not realizing full value from his property. This problem could be lessened were some of the lower grades manufactured into lumber for the furniture and dimension markets. The logger could harvest more trees, thus lowering his costs; and the land owner would realize more in return for his stumpage. Only a small amount of Western Hardwood is made into lumber, with the exception of Alder. The reasons for this are two-fold: (1) small operators have tried to manufacture these woods into lumber and have lacked the necessary capital to finance the large inventories involved in air drying the product, (2) there have been no accurate grading rules. Buyers receive a good shipment one month and a poor one the next month, due to the lack of grading controls. Therefore, the hardwoods have an unfavorable reputation.

As far as drying western hardwood lumber is concerned, several papers on the subject have been published in the *Forest Products Journal,* and generally the methods and schedules have been feasible.

Few problems will arise in the manufacture of veneer and plywood from the western hardwoods providing that diligent care is taken in selecting the logs and that conventional hardwood production methods are used.

Four species of western hardwoods seem to hold the most promise for teh production of veneer and plyplywood:

(1). **Tanoak**—(*Lithocarpus densiflores).* With the exception of alder, tanoak is available in the largest volumes. Primarily, it grows along the Coasts of Southwestern Oregon and Northwestern California. One of its main defects demonstrated in the limited experimentation to date is a predominance of mineral streak. Rotary-cut tanoak veneer closely resembles rift white oak in appearance. This is due to the fact that tanoak veneer possesses almost an indistinguishable growth ring together with small pores and oak-type rays. The market for rift-sliced eastern white oak, although somewhat limited in volume, is lucrative. If the mineral streaks can be controlled there is no question that tanoak will find a home in the veneer and plywood field within the next few years. Additional information on tanoak is available in "Oregon Hardwood Plywood," Oregon Forest Products Laboratory Circular No. 10, by J. R. Pfeiffer and J. L. Overholser.

(2). Pacific madrone—*(Arbutus menziesii)* Several large hardwood and specialty plywood and particle board plants have recently started to use madrone and to measure its market acceptance. The veneer is of a reddish–brown color, similar to eastern cherry in appearance. It takes and holds an excellent finish and is extremely hard. The finest appearance is found in flat-sliced and book-matched veneer, which illustrates the varying grain characteristics and, unique figure of the wood. When produced in this manner, madrone falls into a price category somewhat below eastern cherry, but it is more expensive than some of the more conventional species, such as birch. Madrone grows along the entire Pacific Coast from Canada to Mexico. The largest trees seem to be located in Southwestern Oregon and Northwestern California. Extreme care should be taken in selecting veneer logs, as the species is inherently crooked and defective. This doesn't mean that there are not good logs available. Actually some of the Madrone trees located in concentrated stands grow 50 to 60 inches in diameter. Madrone is probably the most difficult of the Western species to handle in the veneer mill. It is sensitive to water, and it must be carefully prepared for slicing or peeling. It must also be handled carefully at the Drier, as it tends to buckle when dried under too swift a schedule. The veneer is on the brittle side and must be nursed through the splicing department in order to hold falldown to a minimum. However, once the veneer has passed through these operations successfully its appearance certainly offsets any of the extra manufacturing difficulties. There is no question that madrone will have a bright future.

(3.) California Black Oak *(Quercus kelloggii)*—Veneer produced from California black oak is similar in grain characteristics to some of the eastern red oaks. Its color is slightly whiter than red oak but not as white as eastern white oak. Fine veneer can be produced by rift- or flat-slicing, and there is no apparent reason why a good rotary-cut veneer cannot be manufactured. California black oak trees are, on the whole, quite defective and only a small percentage can be used for veneer. Rot is prevalent and knots apper quickly below the sap line. There also seems to be an abundance of mineral steak, but the amount seems to vary from area to area, and most of it can be clipped out of the face-grade veneers without too much loss.

(4.) California Laurel of Oregon Myrtle *(Umbellularia Californica)*—This wood has extremely interesting grain characteristics, and it has no peer as a novelty wood. The wood works easily and holds a finish well. The one big problem with myrtle is that there is no uniformity of grain or color from tree to tree. Whereas flitches or bolts from one area may yield veneer that is predominantly yellow in cast, those from a nearby area might yield veneer with a green or black cast contrasting with the yellow. The same holds true in the appearance of the grain. Due to this lack of continuity of color and grain, it is impossible to treat this species as a production—type veneer. This doesn't in the veneer and plywood field. Individual achitectural specifications have called for myrtle panels in the past, and the results have been most satisfactory. There is no reason why myrtle cannot be used in this same way in the future for custom installations in offices and residences where the specifications could call for panels from one or two chosen flitches.

Conclusion

Western hardwoods definitely have a future in the veneer or plywood field. With 23 billion feet to draw from, and adequate supply of raw materials is available. The eastern hardwoods in the finer grades are growing more and more scarce, while the western species are virtually untapped. The secret to the success of these woods will be the type of promotion used to launch the various species. For the most part, these woods are unknown to the public, and practically any of the present knowledge is of a negative nature. Madrone affords a good example of what can be done providing the wood is given a fair chance. During the past 2 years it has been sliced, book-matched, and sold in the veneer form to 8 or 10 large plywood and particle board plants. All of these plants, seem to be very happy with the species, as are their customers. This point is illustrated by a larger volume of madrone being shipped every month. The other western woods will do the same providing they are given a fair chance.

TECHNIQUES FOR THE DEVELOPMENT OF

A Rational Grading System for Hardwood Veneer Logs

J. S. Bethel and C. A. Hart
School of Forestry, North Carolina State College, Raleigh, North Carolina

Procedures for the collection and analysis of descriptive data for use in the development of grades for hardwood veneer logs are presented. Effect of minimum usable size of veneer clipping on expected yield is indicated.

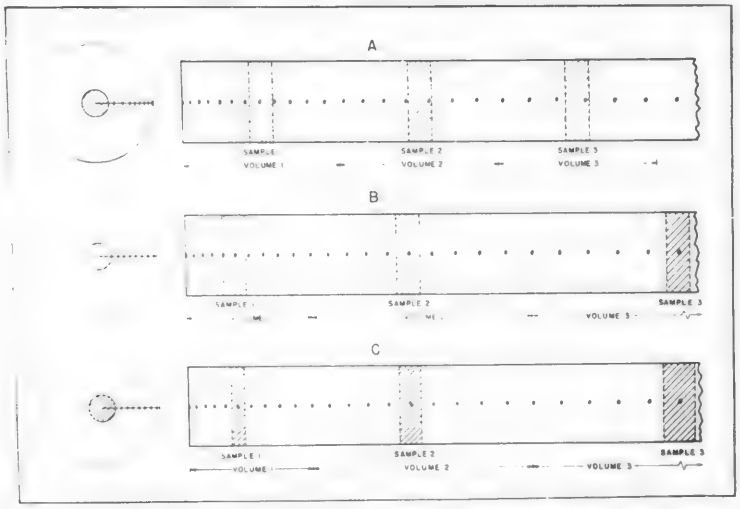


Fig. 1.—Comparison of three sampling plans: (a) Equal sized samples representing equal volumes of wood; (b) Equal sized samples representing unequal volumes of wood; (c) Unequal sized samples representing unequal volumes of wood.

FIFTY YEARS AGO VIRTUALLY ALL hardwood veneer was manufactured from virgin timber. There was essentially only one veneer log grade. A prime veneer log was one that was large in diameter and completely free of visible defects. Now this type of large clear veneer log has become increasingly scarce. Veneer manufacturers today must buy second- and third- growth material. These veneer logs are small in size and contain defects that would not have been tolerated 15 or 20 years ago.

The veneer producer is interested in the usable and saleable veneer that a log contains. It is desirable then to be able to predict how much of this type of veneer can be recovered from a given log so that the manufacturer can determine whether he can afford to use it, and what he can afford to pay for it. A system of veneer log grades constitutes a classification of logs based upon visible external qualities that can be used to predict the potential yield of useful veneer.

The first veneer log-grading systems used involved limitations on the size and frequency of defects. This procedure grew out of the methods used to classify softwood logs and was more suitable to softwood log grading than to hardwood veneer log grading. Among the early systems that were based on this principle, was a set of grades established by the Southern Log Association of Memphis, Tennessee, for the grading of southern hardwood logs.

More recent hardwood log-grading systems have been based upon amount of clear area between defects. The specification for hardwood veneer log grades used by the U. S. Office of Price Administration during World War II was based upon the number of clear quadrant faces in a log. This same principle was used by the U. S. Forest Products Laboratory in developing its present "Hardwood Log Grades for Standard Lumber.[3]

At the present time, there are no standard and generally accepted log-grading rules for hardwood veneer logs. All veneer manufacturing firms have rules that they use as a basis for their log procurement. There is little uniformity among these rules from mill to mill. Furthermore the rules used by a specific mill may be changed from time to time in response to changes in log availability and the pressure of competition. It is not uncommon for a mill to modify its log grade to meet competition instead of changing its price. Since these rules are all based in empericism rather than in experimental evidence there is no rational basis for continuing a particular grading system.

Recognizing the need for experimental evidence upon which to base rational grades for hardwood veneer logs, a group of research and industrial organizations met in Raleigh, North Carolina, in January, 1952. The group included representatives from: North Carolina State College, Duke University, Southeastern Forest Experiment Station, Tennessee Valley Authority, Northeastern Forest Experiment Station, Southern Plywood Manufacturers Association, The Mengel Company, Darlington Veneer Company, Drexel Furniture Company, U. S. Plywood Corporation, General Plywood Corporation.

The Authors: Dr. James Bethel is Director of the Wood Products Laboratory at N. C. State College. Active for many years in FPRS, he has been Chairman of the Carolinas–Chesapeake Section and the Industry-Education Division. C. A. Hart holds a Ph.D. from N. C. State, where he is currently Research Associate Professor in the Department of Wood Products.

[1] Presented at Session IV, Veneer and Plywood, FPRS 12th National Meeting, June 22–27, 1958, Madison, Wis.; received by the Journal September 16, 1959.

[2] A contribution from project number H of the North Carolina Agricultural Experiment Station in Cooperation with the U. S. Forest Service, Southeastern Forest Experiment Station, Asheville, N. C.

[3] Anon. 1953. Hardwood Log Grades for Standard Lumber—Proposals and Results. U. S. Forest Service, Forest Products Laboratory, Report No. 1737.

t was decided to commence a long t[e]rm program designed to develop a g[r]ading system for hardwood veneer l[o]gs, based upon experimental data, th[at] would distinguish among classes o[f] veneer logs in terms of yield of us[a]ble veneer. It was also decided that th[e] field data would be collected in su[ch] a way as to permit a wide variety of analyses. This decision was based up[on] general agreement that the project should not be limited to examining gr[a]ding systems now being used, but th[at] it should be free to recommend an entirely new approach to the problem of veneer log classification, if this proved appropriate.

Log and Veneer Quality

It was clear from the start that it was necessary to examine first the kinds of defects that occur in hardwood veneer logs. Obviously the only external log defects that are of importance in veneer log grading are those that indicate defective veneer in the inner usable portion of the log. Likewise the importance of a defect depends upon how seriously it effects the yield of usable veneer.

Accordingly, the fist portion of this research project was a study of the kinds of defects that occur in hardwood logs and the external evidence of the presence of these defects. This study was conducted by E. S. Harrar,[4] who was then a Technologist with the Southeastern Forest Experiment Station.

Sampling Procedure

The second phase of the research was concerned with the development of a sampling plan that was appropriate to the determination of veneer yield from hardwood logs. For the purpose of this investigation 30 veneer bolts were cut into one-eighth inch veneer (actually, 0.128 inches) on the rotary lathe in the North Carolina Wood Products Laboratory. All bolts were spurred to yield veneer 36 inches in length. The distribution of bolt diameters was as follows:

Bolt Diameter (inches)										
12 to 13	13 to 14	14 to 15	15 to 16	16 to 17	17 to 18	18 to 19	19 to 20	20 to 21	21 to 22	Total Bolts
Number of Bolts										
1	1	7	4	4	2	3	3	0	2	30

The bolts were chucked as near the geometric center of gravity of the end section as possible. Veneer was collected for measurement as soon as it provided piece or whole stock that would yield a 6-inch wide cutting. From this point, all veneer was taken for measurement until a 4½-inch diameter core was dropped. In the few cases where it was not possible to continue cutting to a 4½-inch core, the linear feet of veneer to a 4½-inch core was computed using the following formula:

$$D = \frac{\pi [R^2 - (2.25)^2]}{(.128)\ (12)}$$

Where:

D = difference between the linear feet of veneer obtained and the linear feet that would have been obtained if the bolt had been cut to a 4½-inch core.
π = 3.1416
R = radius of the actual core (inches)

Following the cutting operation, all of the veneer from each bolt was examined, and defects were identified, measured, and recorded. Actual veneer yields were measured in terms of four grades of cuttings; clear, sound, solid, and reject. The minimum width of a cutting was 6 inches (i.e., cuttings less than 6 inches wide were not considered as usable yield). These actual yields then served as the criterion for evaluating the accuracy of the proposed sampling plan.

Several possible sampling plans were considered. Figure 1 illustrates the three plans that were given major consideration. In plan A, the samples are of equal size and are spaced at equal intervals along the veneer sheet, thus being located at unequal distances along the bolt radius. Therefore, each sample represents the same volume of wood. In plan B, the samples are also of equal size, but they are not spaced at equal intervals along the sheet of veneer. Instead, they are spaced at equal intervals along the bolt radius. Thus, we have samples of equal size representing unequal volumes of wood. In plan C, the samples are of unequal size, and they are proportional to the bolt circumference at the point where they are taken. Logically each sample would be a complete revolution. The samples are spaced at unequal intervals along the veneer sheet, but they are at equal intervals along the bolt radius, Thus, we have unequal samples representing unequal volumes of wood, but the sample sizes are equally proportional to the volumes they represent.

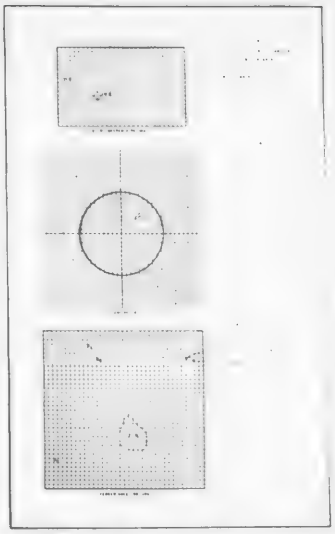


Fig. 2.—Record sheets used to diagram log and veneer defects.

Ease of application is an important criterion for selection of a sampling plan. From this standpoint, plan A was readily judged to be the superior plan. It has several important attributes. First, it is relatively easy to locate samples at equal intervals along a veneer sheet. Second, the physical handling of samples and the recording of data are greatly facilitated by

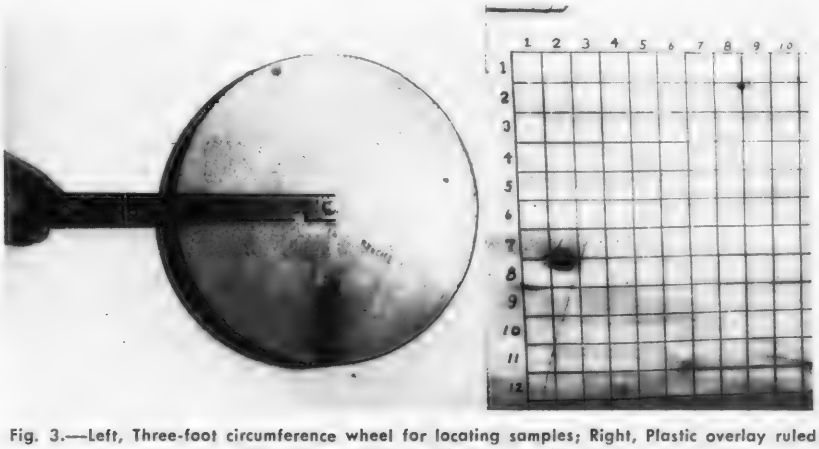


Fig. 3.—Left, Three-foot circumference wheel for locating samples; Right, Plastic overlay ruled in 1-inch squares for locating veneer defects.

[4] Harrar, E. S. May 1954. Defects in Hardwood Veneer Logs. Southeastern Forest Experiment Station Paper No. 39.

[5] Handle, David O. 1954. A Method of Sampling the Yield from Yellow Poplar (*Liriodendron tulipifera* L.) Veneer Bolts. Unpublished M. thesis in the Library of North Carolina State College, Raleigh, North Carolina.

the fact that all samples are of equal size. Third, in analysis of sample data, no weighting is required since the equal sized samples also represent equal volumes of wood.

In order to evaluate its accuracy, sampling plan A was applied to the 30 bolts for which the actual yield had been determined. A 3–foot sample was taken at 30–foot intervals on ⅛ inch veneer. A comparison of sample yields to actual yields for all four grades of cuttings showed the sampling plan to be satisfactory. Further evaluation with regard to sample size resulted in the adoption of the 3–foot sample for every 30 feet of ⅛ inch veneer.

This sampling plan may be easily applied to bolts of variable lengths and veneers of various thickness. The sample is always 3 feet wide and it may be full-bolt length or less than bolt length, if it is desired to sample only a portion of long bolts. For various veneer thicknesses, a graph showing the linear equivalent of the given thickness to 30 linear feet of ⅛ inch thickness readily permits the proper location of samples. Thus, the data may be evaluated without regard to the actual thickness of veneer that was cut. If samples vary in length, however, those of different lengths cannot be properly averaged, as greater length increases the probability of defects and lower yields.

It is important that one characteristic of this sampling plan be stressed. It is biased to some extent in predicting yields in some types of commercial operations. Many veneer plants clip green veneer for uniform size without regard to defects, subsequently clipping for grade after drying. With this practice, long sheets of veneer are usually stacked before the green clipper and then clipped at a fixed interval to uniform size. When the fixed clipping interval is 3 feet, the sampling plan employed in the present study is directly applicable, disregarding drying degrade. For intervals greater than 3 feet, and for single sheet clipping for grade rather than size, yields would theoretically be higher than those indicated by the sampling plan employed in this study, particularly for the larger minimum widths of cuttings. The exact extent of this bias is being evaluated as this study continues.

Data Collection Procedures

Before a system of log grades for hardwood veneer can be developed that will accurately reflect yield of usable veneer, it is necessary to know how such factors as type, size and location of defect, bolt size, and minimum size of clear cutting are related to yield.

To evaluate these factors, studies were conducted at eight southern plywood plants located in North Carolina, South Carolina, and Georgia. All bolts were measured and diagrammed just before debarking. The bolts were of various mill-run lengths, but only a 3–foot section from the small end was diagrammed and sampled. The 36–inch by 36–inch veneer samples were obtained according to the sampling procedure previously described. Figure 2 shows the type of record kept on bolts and veneer samples. Figure 3 illustrates a counting wheel and a plastic overlay used to locate samples and describe defects found on the veneer.

For ease of recording and for later identification and processing on electronic data processing equipment defects were coded as follows:

Identification Code

Species Number:

1. Red gum *(Liquidambar styraciflua L.)*
2. Black gum *(Nyssa sylvatica L.)*
3. Yellow poplar *(Liriodendron tulipifera L.)*
4. Water tupelo *(Nyssa aquatica L.)*

Log number (starting with 001)

Log diameter (actual diameter measurement to the nearest inch outside bark at the small end)

Log Code—Side Surface

1. Clear area (actual width measurements in inches)
2. Knots (width in inches)

1. ½	6. 3	11. 5½
2. 1	7. 3½	12. 6
3. 1½	8. 4	13. 6½
4. 2	9. 4½	14. 7
5. 2½	10. 5	15. 7½

3. Holes (width in inches)

1. ½	6. 3	11. 5½
2. 1	7. 3½	12. 6
3. 1½	8. 4	13. 6½
4. 2	9. 4½	14. 7
5. 2½	10. 5	15. 7½

4. Burls (width in inches)
   1. Small (less than 2 inches)
   2. Medium (2 to 4 inches)
   3. Large (over 4 inches)
5. Bird peck (actual width measurement in inches)
6. Tension wood (excessive crook)
7. Adventitious buds (width in inches)
8. Seams (actual width measurement in inches)
9. Dormant buds (width in inches)

1. ½	6. 3	11. 5½
2. 1	7. 3½	12. 6
3. 1½	8. 4	13. 6½
4. 2	9. 4½	14. 7
5. 2½	10. 5	15. 7½

10. Bumps
    1. Low (taper less than 1 to 3)
    2. High (taper greater than 1 to 3)
11. Butt scar
    1. Slight (no visible decay)
    2. Medium (slight decay not over 4 inches wide)
    3. Severe (advance decay over 4 inches wide)
12. Butt swell
    1. Slight
    2. Medium
    3. Pronounced
13. Spiral bark
14. Overgrowth (width in inches)

1. ½	6. 3	11. 2
2. 1	7. 3½	12.
3. 1½	8. 4	13. 2
4. 2	9. 4½	14.
5. 2½	10. 5	15. 2

Log Code—End Surface

1. Flag worm (length of d ay streak along radius in inches)

1. ½	4. 3	7.
2. 1	5. 4	8.
3. 2	6. 5	9.

2. Gum spots (average widt in inches)

1. ½	4. 2	7. 2
2. 1	5. 2½	8.
3. 1½	6. 3	9. 2

3. Heart rot
   1. Slight
   2. Medium
   3. Advanced
4. Pith flecks
   1. Small (less than ¼ inch)
   2. Medium (¼ to ½ inch)
   3. Large (over ½ inch)
5. Loose heart
6. Wind shake (length of spli in inches)
   1. Under 4½
   2. 4½ to 8
   3. Over 8
7. Stain
   1. Blue
   2. Fire streak
   3. Blue butt
   4. Brown
8. Spider heart (length of sp in inches)
   1. Under 4½
   2. 4½ to 8
   3. Over 8
9. Double pith
10. Ring shake
11. Out of round
    1. Slight (pith 2 inches m center)
    2. Medium (pith 2 to 4 i es from center)
    3. Severe (pith over 4 i es from center)

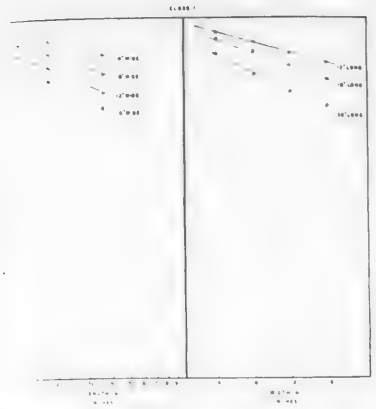


Fig. 4.—Yield curves for various size cuttings of clear veneer from Class 1 bolts.

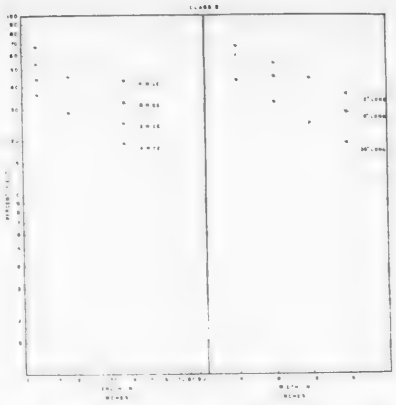


Fig. 5.—Yield curves for various size cuttings of clear veneer, from Class 2 bolts.

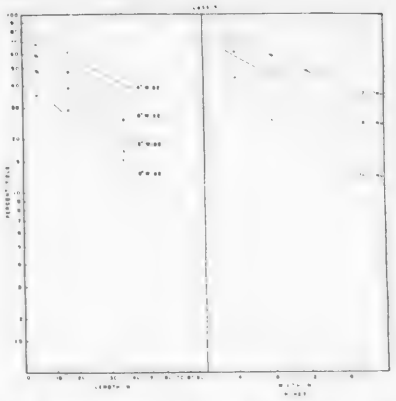


Fig. 6.—Yield curves for various size cuttings of clear veneer from Class 3 bolts.

Veneer Code

1. Clear veneer (actual width measurement in inches)
2. Sound knots (width in inches)

1. 1/8	8. 1	15. 4 1/2
2. 1/4	9. 1 1/2	16. 5
3. 3/8	10. 2	17. 5 1/2
4. 1/2	11. 2 1/2	18. 6
5. 5/8	12. 3	19. 6 1/2
6. 3/4	13. 3 1/2	20. 7
7. 7/8	14. 4	

3. Knot holes (width in inches)

1. 1/8	8. 1	15. 4 1/2
2. 1/4	9. 1 1/2	16. 5
3. 3/8	10. 2	17. 5 1/2
4. 1/2	11. 2 1/2	18. 6
5. 5/8	12. 3	19. 6 1/2
6. 3/4	13. 3 1/2	20. 7
7. 7/8	14. 4	

4. Burls (width in inches)

1. 1/8	8. 1	15. 4 1/2
2. 1/4	9. 1 1/2	16. 5
3. 3/8	10. 2	17. 5 1/2
4. 1/2	11. 2 1/2	18. 6
5. 5/8	12. 3	19. 6 1/2
6. 3/4	13. 3 1/2	20. 7
7. 7/8	14. 4	

5. Bird pecks (actual width measured in inches)
6. Tension wood (Fuzzy veneer, actual width measured in inches)
7. Pin knot clusters over 4 pin knots per square inch (actual width measured in inches)
8. Splits (actual width measured in inches)
9. Shake (actual damaged width measured in inches)
10. Worm holes (width in inches)

1. 1/8	4. 1	7. 4
2. 1/4	5. 2	8. 5
3. 1/2	6. 3	9. 6

11. Decay, cross-break, bark pockets, gum pockets, rough veneer, and local cross grain (actual width measured in inches).
12. Pin knot veneer (actual width measured in inches of veneer containing 4 or more pin knots per square foot. Pin knots are to be groups where the individual knots are not separated by more than 3 inches in any direction).

Preliminary Analysis of Data

Prior to the development of an electronic computer program, the veneer sample diagrams for the red gum (*Liquidambar styraciflua* L.) were examined visually and descriptive data tabulated. Each sample was examined for yield as though it were (1) cut into a single 36-inch ribbon, (2) spurred into two 18-inch ribbons, and (3) spurred into three 12-inch ribbons. All analyses were made on the basis of clear cuttings only. In each category of veneer length, yield was estimated in terms of 4-, 8-, 12-, and 16-inch minimum clear cutting widths.

For the purpose of examining the effect of bolt quality on yield, the bolts were arbitrarily separated into six classes based upon the presence of defects and their location as follows:

Class 1. No visible surface defects
Class 2. Defects on only one quadrant surface
Class 3. Defects on only two adjacent quadrant surfaces
Class 4. Defects on only two opposite quadrant surfaces
Class 5. Defects on only three quadrant surfaces
Class 6. Defects on all four quadrant surfaces

Figures 4 through 9 show the yield curves for the six classes of bolts examined in terms of length of veneer (along the grain) and minimum width of clear cutting (across the grain). For each bolt class, the relationship between the logarithm of the percent yield of clear cuttings and the logarithm of length was found to be linear. The relationship between the permissable minimum width of clear cutting and the logarithm of the percent yield of clear cuttings was also found to be linear. It is apparent that the quality of the bolt as evidenced by the occurrence of external defects influences the yield of clear veneer. This effect is particularly pronounced when minimum acceptable cutting widths are large and veneer cutting lengths are long.

It may be noted that yield decreases rather rapidly with increasing minimum width of cutting. As previously indicated, the sampling plan employed is directly applicable only to the practice of green clipping at a fixed interval of 3 feet prior to clipping for grade. Where single sheet clipping for maximum yield is employed, or multiple sheets are clipped at intervals greater than 3 feet, yield would not decrease as greatly with increasing minimum width.

Figures 4 through 9 fail to indicate a completely consistent reduction in yield with decreasing bolt quality. Class 6 bolts exhibit slightly higher yields than class 5. As Rand[6] points out, bird peck was often responsible for placing bolts in class 6, and this bolt surface defect does not necessarily indicate that defective veneer will be obtained. Such factors as this must be evaluated for development of a satisfactory log grade.

Figure 10 indicates the effect of bolt diameter on yield as related to the samples on the radius of the bolt. The evidence presented in this graph is worthy of discussion. It has been the practice of the veneer industry to specify minimum diameters in the procurement of veneer logs. There are several reasons for this practice. In every rotary veneer cutting operation there is a minimum veneer core that must be discarded. The size of this core, of course, is related to the size of the lathe spindle and the chuck being used. In the United States,

[6] Rand, Leroy F. 1955. Some Factors Influencing the Yield of Red Gum (*Liquidambar styraciflua* L.) Veneer. Unpublished M.S. thesis in the Library of North Carolina State College, Raleigh, North Carolina.

Fig. 7.—Yield curves for various size cuttings of clear veneer from Class 4 bolts.

Fig. 8.—Yield curves for various size cuttings of clear veneer from Class 5 bolts.

Fig. 9.—Yield curves for various size cuttings of clear veneer from Class 6 bolts.

lathes generally utilize large spindles and chucks. In some European countries where small diameter veneer logs are the rule, it has been found practical to use small diameter spindles and chucks. Obviously, the diameter of the bolt must be substantially greater than the diameter of the chuck if enough veneer is to be obtained to pay for the processing of the log. The time required to handle and chuck a large log is not appreciably greater than that required for a small one.

When veneer logs were obtained largely from virgin timber it was reasonably safe to assume that a clear log of large diameter would yield a substantially greater volume of clear veneer than a clear log of small diameter. In the growth of the stand natural pruning would remove the lower dead branches and after that the longer a tree lived and grew before cutting, the thicker was the sheath of knot free wood. Under these circumstances the inclusion of a fairly large minimum diameter limit in veneer log specifications was reasonable.

Today, however, most hardwood veneer logs are being obtained from stands that have been high-graded for veneer logs from one to several times. When a large clear log is obtained from such a stand, it is likely to be from a tree that was passed over in previous cuttings because of the presence of defects. Accordingly, the sheath of defect-free wood may be very thin. When this is true, the advantage of specifying a large minimum diameter may not be great.

The data presented in Figure 10 suggest that the sheath of clear veneer on the outside of mill-run veneer logs is on the average about the same thickness regardless of diameter. If this is true, the mill that must have a high percentage of clear face material might be in a better position if it concentrated on the procurement of smaller clear logs. On the other hand, the mill that can utilize large quantities of low grade veneer can reduce its unit veneer manufacturing costs by purchasing large diameter logs.

Another limitation on the use of small diameter hardwood veneer logs is that it is more difficult to cut tight veneer from small diameter logs than from large diameter logs.

Since grades for hardwood veneer logs are based upon the presence or absence of external visible defects, it is apparent that the yield that can be expected from logs that qualify as clear will be highly variable. The evidence presented in Figure 10 argues strongly for the management of hardwood veneer timber stands. If the history of a timber stand was well known at the time of cutting, veneer log grades would have much more meaning.

Current Status and Objectives

In order to effectively use the field data to establish a satisfactory log-grading system, it was necessary to develop an analytical technique that would permit the data to be rapidly processed in a number of ways:

1. A substantial number of possible log-grading systems must be compared as applied to the same group of logs.
2. It is necessary to be able to modify systems and re-analyze for comparative purposes.
3. The most promising veneer log-grading system must be analyzed in terms of several different veneer quality criteria.

It became obvious early in the development of analytical techniques that the only way that this volume of data could be subjected to a multiple analysis was through the use of electronic data-processing techniques. Accordingly, a program has been developed for use with an IBM Number 650 Magnetic Drum Digital Computer that will permit this type of analysis.

Although a detailed description of the computer programming is beyond the scope of this paper, a brief summary of the general methods and techniques being employed should prove worthwhile. As previously pointed out, the individual veneer samples are 36 inches wide and of variable length, depending upon the bolt length. Thus, in effect, a veneer sample diagram may be considered as consisting of 36 rows with each row being 1 inch in width. Within each row, the location of a given defect may be described by noting the starting point and the ending point by block number. Thus, the de-

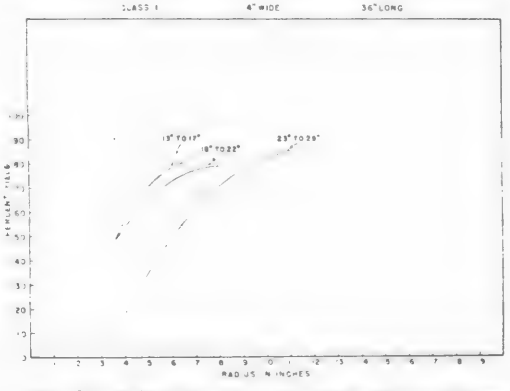


Fig. 10.—Yield of clear veneer for three diameter classes of Class 1 bolts. Minimum width of cutting was 4 inches and length of cutting was 34 inches.

fect location is completely described by recording its position across the grain by row number and its position along the grain by the starting column or block number and the ending block number.

With the computer program in current use, a separate IBM data card is used for each of the 36 rows that contain one or more defects. If no defect is present in a given row, no card is required for that row. If more than six separate defects are present in a given row, a second IBM data card will be required since this is the maximum number of defects that can be recorded on a single card. However it is rare that more than six defects will occur in a single row.

On each data card is recorded the identification information of mill number, log number, bolt number, sample number, bolt length, and row number. For each defect, the starting block number, ending block number, defect type, defect size, and frequency are recorded. The computer examines each successive row of a given sample and either accepts or rejects the row. In this method of row-by-row examination, a defect that appears in several rows must be recorded separately for each of the rows. Thus, the term "frequency" refers to the fact that the first recording of a defect is noted so that the frequency of occurrence of various types of defects may be tabulated despite the fact that a given defect may be recorded in several rows.

The veneer-defect code previously shown lists the types and sizes of defects as they have been included in this study. In the computer analysis, the computer may be instructed to disregard any defects that the operator desires; that is, the chosen defect or defects do not cause the row or rows in which they appear to be rejected. Thus, the effect upon yield of any specific type or size of defects or combination thereof may be readily determined.

In a single run, the present computer program provides for the determination of yield for any preselected minimum width of acceptable cuttings. Each row of each sample and each sample of each bolt is examined, and the resulting yields are calculated and punched on output data cards. For each bolt, a single output data card is obtained which shows the percent yield of that bolt in six different minimum acceptable cuttings. These cards may then be readily sorted and tabulated by various trial log or bolt grades as desired. Also, repeated runs of the input data cards may be made, using various combinations of acceptable defects and additional yield or output data cards obtained for each bolt.

Thus, it may be seen that various proposed grading systems may be examined and compared using numerous combinations of minimum acceptable cuttings with many combinations of acceptable defect categories. This is a major objective of this continuing study at the present time. The exact nature of the sampling plan bias and the relationship between the yield efficiency of various commercial clipping practices is also being evaluated.

Lumber Mill Integration ...

FROM WOODS TO CAR DOOR[1]

The case history of a forest products center and how it is managing the timberlands for sustained yield, using all the wood on the land and all parts of the tree, and producing products of highest possible value.

N. T. SHELTON
Diamond Gardner Corporation,
Chico, California

AS A RESULT OF THE INCREASED DEmand for wood fiber along with the increase in stumpage values, many companies within the industry have come close to utilizing all of the products that the forest soils will produce. This has given meaning to the term "integration". As applied to the lumber industry, we have interpreted integration to mean

(1) Managing the timberlands to produce its maximum sustained yield capacity
(2) Utilizing all wood on the lands and all portions of the tree
(3) Obtaining the highest value from the utilized portions of the tree.

A high degree of this type of integration has been achieved by others. The Diamond Gardner Corporation is also attempting to reach this objective at its forest products center which started operation in 1958 at Red Bluff, California.

Managing Timberland For Maximum Sustained Yield

If our definition of integration is correct, it is apparent that it starts with management of the timberlands. Therefore, a forestry program has evolved with selective harvesting and forest protection as its basic form. The forestry department has established a reasonably accurate inventory of its timber by size, density, and species and a knowledge of the probable rate of growth by observation of several permanent growth plots. With this information, the foresters have set up annual cutting cycles and a harvesting program to determine which areas, of the 220 thousand acres of timberland in the Sierra Nevada Range, are in greatest need of cutting.

The harvesting program is planned carefully in advance of logging and the trees to be removed are marked by the foresters as determined by age, rate of growth, general health, insect risk, mechanical risk, amount of decay, value of merchantable timber in the tree and the number of adjacent trees to be left standing. In this way, the mature, over-mature and high-risk trees are removed by the logging crews, leaving the healthy, younger trees for a future crop and natural reseeding. The stand is opened up, providing more room for the younger trees to start and resulting in a more rapid growth of the trees which are left standing. By balancing the cutting cycle and the number of trees taken with the growth of the stand, the timber resources can be placed on an annual sustained yield basis.

The elaborate process of establishing harvesting programs and managing the lands on a sustained yield basis would be futile, of course, if the forests were not protected against destruction by fire. To provide this protection, more than 900 miles of roads

The Author: N. Thomas Shelton is Chief Industrial Engineer of Diamond Gardner's Lumber Division at Chico, Calif. He holds a degree in mechanical engineering from Cornell University.

[1] A condensation of a paper presented at Session X, Lumber Manufacturing, FPRS 13th National Meeting June 30, 1959, in San Francisco.

give quick access to almost all parts of the holdings and new roads are being built at the rate of approximately 50 miles annually. An extensive radio system links all field equipment and personnel so that trained fire-fighting crews, water trucks, bulldozers and other equipment can be dispatched immediately to any fire that starts. Company fire patrolmen cover the tree farm daily during the fire season. In cooperation with other companies, airplanes are used as an auxiliary fire detection service in cooperation with lookouts and patrols provided by federal and state agencies.

Protection of the forests against destruction by fire and selective cutting has a double barrelled result since it promotes natural reforestation of the lands. Experimentation in planting and reseeding has gone on continuously from 1908 to the present. These efforts have not been entirely successful, however, due to rodents, rigors of transplanting and differences between natural and artificial seed beds. At the present time, seeding and planting is confined on a limited scale to burns, areas cleared for improvements, large log landings, and stands that do not adequately regenerate themselves by natural means. More recently, experiments with fertilizers have been made on forest soils that are deficient in some of the key minerals required for the growth of plant life.

Utilizing All Wood on the Lands and All Portions of the Tree

Before the turn of the century, large areas of the western forests were clean and open. The trees were tall and contained five clear logs but none of the loggers ever went beyond the first limb. A rule-of-thumb for yellow pine was "three logs and leave her." In contrast with the early day wasteful practices, Company foresters mark the mature, over-mature and high risk trees to a minimum utilization standard that includes logs 10 feet in length with a 10-inch top diameter. A pine tree is considered merchantable if it contains one-third net scale, and mixed specie is cut if the log is one-half sound. Stumps are cut generally not more than 14 inches above the ground.

A few years after an area is selectively harvested, crews return for a relog and salvage operation. Second-growth areas are thinned, and trees that were missed by the original crews are removed. At the same time, trees likely to die due to a temporary build-up of beetles and trees that have been knocked down or damaged are salvaged. The minimum utilization standards for thinnings are lengths of 10 feet and top diameters of 7 inches; thinnings and tops below 7 inches in diameter are marketed as fence posts.

In many of the young stands of second growth, there are two thousand stems or more per acre but it can be anticipated that only about one hundred stems per acre will reach maturity as merchantable sawlogs. This natural mortality is utilized as much as economically feasible in the form of Christmas trees, posts, poles and small sawlogs.

From the start, an effort has been made to utilize black oak, but the amount harvested has never exceeded 500,000 BF per year. Recently an all out effort has been made to determine whether it is economically feasible to harvest this oak along with the mixed conifers. Other research is underway to determine recovery after sawmilling and the best kiln drying techniques. A market survey of finished products, such as flooring, furniture, wood parts and particle board, has also been made.

Obtaining Highest Value from Utilized Portions of the Tree

In the fully integrated operation, emphasis is placed on getting the highest possible overrun and making sure lumber is produced in a form that gives it the highest possible value. To achieve this result, the sawmill has been equipped with three double-cutting headrigs—a 72-inch opening carriage for sawing the large logs, a small, fast 48-inch carriage for handling thinnings and the smallest sawlogs; and a 54-inch carriage to take care of the intermediate log sizes. The three edgers in back of each of the headrigs are fully automated, with pushbutton control of the transfer chains, edger feed, and saw shifters. Lumber from each of the headrigs can be diverted to either of the two selective trimmers. Mechanical aids include positive bar stops at the log-cut off saw, taper knees on the log carriages, shadow-line edging and trimming, and a dip tank for stain control.

A resaw in back of the trimmers is provided with run-around transfer chains. After resawing, lumber may be upgraded by re-edging and re-trimming. If lumber can be further upgraded, it is marked by the grader, pulled into a separate unit, and returned by crane to the sawing floor for re-edging or re-trimming.

Specialized equipment makes it possible to sort and band logs by species in order to avoid sawing all species during the same shift and to separate wood chips by species.

From the log pond to the car door, through the sawmill, lumber stacker, dry kilns, blanker, dry sorter and surfacing facilities, logs and lumber remain under cover and are transferred from one operation to the next by means of transfer chains, roll cases, and bridge cranes to minimize degrade and handling damage.

So-called factory grades of lumber are remanufactured into mouldings, box shook, beehives, door jambs, window frames, furniture and parts, finger-jointed stock, and edge-glued panels. Cut-to-length, packaged panelling is produced in either unfinished, furnished, or pre-finished forms. A more recent development is a decorative board paneling for which a variety of unique design motifs have been created by means of a routing and silk screen process.

A plant for the production of prefabricated vacation cabins, utility buildings, tract houses, and residential roof trusses is now in operation. This has the effect of increasing the sales value of Douglas-fir and white fir dimension grades, and it provides an outlet for other wood products.

A quality control program has been set up to measure and take corrective action on control of dimensional tolerances, seasoning defects and surfacing quality. The research and product development staff is working continuously toward utilizing the timber resources in products of greater utility and value.

Utilization of Mill Residuals

Mill output averages one hundred million board feet per year. For every one thousand board feet of lumber produced, the wood fibre in the total log volume is broken down roughly as follows:

	Percent
Hogged bark	19
Chippable material recovered as wood chips	17
Chippable material not recovered as wood chips	3
Green sawdust	13
Dry shavings, sawdust and hogged trim ends	13
Finished lumber	15
	100

A great deal of effort has gone into obtaining the 45 percent volume of finished lumber, but we would fall far short of our objective of a fully integrated plant if the remaining 55 percent of the log were not utilized.

The mill at Red Bluff, California includes a whole log barker and a chipping and screening plant which is capable of producing a clean, uniform wood chip from the slab, edging, trim and defect residuals of the sawmill. The chips are delivered by high pressure air line to the pulp mill where they are processed into groundwood pulp for molding, into egg cartons, food trays, and plates. The pulp mill has a production cycle of 75 tons per day and utilizes the entire chip output with the possible exception of chips from Douglas-fir.

In the pulp mill, the chips are ıded into Bauer rapid cycle digesters l treated with hot water under hy-·static pressure to give the chips a form moisture content for refining ·ditions. The refining process takes :e in a Bauer Pressafiner and pri-y and secondary attrition refiners. additional refiner handles rejects n screens and stock cleaners to be back into the system. After refin-a bleaching agent is added, the k is pumped into a cleaning sec-. accepted stock goes to the thick-·rs and from here is delivered on demand to the molded pulp stock chests.

The remaining residuals, consisting of hogged bark, sawdust, shavings and hogged trim ends, are utilized to produce 77½ million pounds of steam per month. Despite the heavy steam requirements, an excess of about 1000 units of wood fuel remains. Investigations are underway regarding the feasibility of utilizing this excess together with residuals produced by mills in the immediate vicinity for the production of charcoal briquettes.

One of the earliest attempts at integration was expressed by Henry Yesler, who built the first steam sawmill on Puget Sound in 1853. "The sawdust we filled swamps with and the slabs we built a wharf with," he reported. Although we have progressed a long way since that time, we are in no position to belittle this early effort because it is quite possible that a reader of this paper 50 years hence may find our present day efforts just as feeble by comparison.

The Lumber Industry's Stake In Education

The forest products industry must shake loose from time-honored opinions as to what can be done. Each segment must invest in an educational effort in behalf of better products and consumer promotion.

R. H. Gloss
Timber Engineering Co.,
Washington, D. C.

THE INDUSTRIAL EXECUTIVE WHOSE basic impulse is not to resist ideas on intangibles, such as promotion, research, and education, to name but three, is the exception. Fortunately most of our executives have come not only to accept but to appreciate the role of intangibles in charting their company's future; they acknowledge that the intangibles of 10 or 20 years ago had a firm part in putting their company where it is today; and that tomorrow's role was probably already written 5 years ago.

What has this to do with education? Simply that education is one of the important numbers in the "combination" for survival; necessary to progress, and the foundation on which any industry must build for the future. Education answers to many names: salesmanship, publicity, advertising, promotion, research and development —to name a few which are usually associated with industry activity.

A salesman is educated, some may say trained, to know his product well, and educated in how to sell that product in competition with other similar or alternate products. Good salesmanship educates the buyer to value received, not merely to "what's the cost."

Publicity, advertising and promotion are those indirect education efforts which help establish a firm's name and product and which create opportunities for more direct "educational" activities.

Research and development are more closely associated with education because in most fields this work is done by more "educated" people, but the important aspect of research and development is not the people who do it but the results—the "educated" products and processes, the "educational" data or ammunition essential to sales progress.

Grant for a moment that industry subscribes to the importance of salesmanship, promotion and research; whether they think of it as education is unimportant. But what of industry's stake in education in the more common sense of the word? What, if anything, must industry do in either the general field of education or in some specific fields in which every firm has some tangible interest? What specific objectives are important to the forest products industries?

The challenge to the lumber industry is not substantially different than the educational challenge to the entire nation. The industry already needs more trained men, and there is every evidence of a sky-rocketing demand as the industry moves ever toward integrated and more mechanized operations, and toward more finished or manufactured products in place of raw lumber. Unless additional raw manpower are put into the schools today, there will be insufficient technical know-how, 4 or 5 years hence.

Not only must the industry help get the raw manpower into the process, it must assist the schools in tailoring the process, the courses, to the end product desired. The technical people are urgently needed if the current defense of lumber markets is to be successful; and even more essential to the offensive program which will naturally follow to round-out the team effort for a progressive industry in the future.

What does offense and defense of markets have to do with education? To answer that question indirectly one has only to reflect on the competition, which has used its educated head to find the answers to its problems. It has been able to attract the volume of men from whom MUST come the ideas which advance any industry, and it has the foresight and patience to plan and to invest far in advance of actual need. Education must provide the people with know-how; the industry which does not offer sufficient promise to attract young blood is thereby forecasting its own decline.

Collective Need—Collective Effort

What is the lumber industries stake in education? Simply its collective FUTURE; *collective* in the sense of the position of the industry and whether it grows and prospers—or whether it continues to trade primarily on what nature has given it

e Author: Ralph Gloss, a professional struc-engineer with 17 years experience in wood nd promotion, is Vice-President and Sec-of Timber Engineering Co

[1] Presented at Session XV, Industry-Education, FPRS 13th National Meeting, July 1, 1959 in San Francisco.

and is content to accept a steadily diminishing role in its present major markets—let alone find any substantial new markets. There will always be a lumber market; the primary question is will it be a healthy one for a large number of firms or only for a select few.

There are many problems and many avenues of approach. Robert M. Ingram, Past-President, National Lumber Manufacturers Association suggested "a comprehensive, carefully considered, 10-year plan to cover the entire era during which our industry will be called upon to prove its worth or be prepared to accept the role of a second-class power in the building products field." Mr. Ingram called for action "as individual manufacturers, as members of regional lumber associations, and as members of national organizations" on a five-front program to:

1. Expand research.
2. Improve manufacturing processes and find new uses for wood.
3. Strengthen and expand distribution channels and develop a closer relationship with all outlets.
4. Ascertain that the product is suitable to its intended use and then properly used.
5. Increase salesmanship—merchandizing and promotional activities at all levels.

Three of these five points—research, processes, and proper use—can only be accomplished with "educated" people; the remaining two—distribution and salesmanship can be most effective with "educated" support.

It is the last of the five points, merchandizing and promotion, on which such a fine start has been made in the National Wood Promotion Program of the NLMA; there is good evidence that the NWPP is only the awakening of the lumber industry through its regional and national associations and that much is yet to come.

For discussion, let us divorce the less direct technical aspects of education and concentrate on those phases of education relating to research, manufacturing, and design. What is industry's stake, its role, both collectively and singly in these three general fields of education?

Each firm in the forest products industry can and should share in the education effect which will ultimately better the industry. The cooperative efforts directed specifically to our forestry schools should be supported by all. Each firm should encourage the groups it supports to join in the cooperative effort of FPRS and NLMA as represented by the Opportunities Unlimited booklet recently published. Each firm can see to it that such literature reaches councillors, and that high school students have an opportunity to see it.

The cooperative effort must not cease with one booklet; a continuing series on the same theme is warranted, and similar booklets keyed to specific regions may be even more effective. Many companies today are tying personnel promotion to plant locations, and various segments of the lumber industry could well outline career opportunities in their industry coupled with the attractions of living in their geographical area.

There is a parallel between the current feeling on politics and that on education. Those who know are urging individual firms and people from industry to take an active interest in politics; they say we can no longer "let Joe do it" or discharge our responsibility by contributing to the party. In a similar sense, we should not expect the schools alone or the various regional and national groups to do the job; these efforts need strengthening but—the most effective program will be that which brings individual firms into the picture at the local level.

Research

No word holds a more unique claim to fame than the simple word research. Many people, frankly, are probably tired of hearing it. It's a magic word which we have been told holds the answer to the industry's problems, but we even have difficulty defining it, or distinguishing between various so-called types of research. How many of us subscribe to "research", perhaps in the same sense that we're "agin sin", without really being sold. It's fashionable to talk of research, but unfortunately too many seem to think someone else has the responsibility to support research with dollars instead of words. The failing must be in our lack of salesmanship.

How many times have we heard that if we could only make the objective of a proposed program more concrete someone would be glad to pay for the work? But could it not be true that the things we need to know the most are those things which we don't know we're looking for?

The remarks of Dr. James R. Killian, Jr., Special Assistant to the President for Science and Technology, are worthy of repetition. Dr. Killian quotes research scientist Hans Selve "that the more manifestly sensible and practical a research project, the closer it is to the common-place we already know. Thus, paradoxically, knowledge about seemingly most far-fetched impractical phenomena may prove the likeliest to yield novel basic information, and lead us to new heights of discovery".

Dr. Killian speaks largely of basic research in the atom and space and deplores our lack of attention by comparison with our world competitors. If the billions being spent on defense department research represent too little, then the lumber investment in basic research can only be described as molecular.

The most disappointing aspect of basic research in lumber is that the problems for which research might find the answer are relatively well-known, and some avenues of study are rather well charted, and yet little or no work is being done on these tangible problems, let alone investment in *uncommitted* research. The future of the lumber industry 10 years hence may lie with the tangible problems which are recognized today, but it is just as likely that the future 20 years hence could lie in the findings of truly *basic* research where the investigator is not concerned with finding the answer to a practical problem, but only in finding basic data, building a fund of knowledge, upon which we more practical people might draw. It has been said that many of our more important discoveries, the break-throughs, would *not* have occurred if a typical industry approach had been taken; this applies to any industry but more so to the lumber industry where by and large the rugged individualist still holds forth, unfettered by the knowledge or confidence in what technical development might bring forth.

A way must be found to sell the industry, collectively and individually, on research. It need not and should not be all basic but should encompass a balanced industry program. Support must be widespread, and it must be long-term if any real progress is to be made.

The collective industry responsibility lies in recognizing the need and financing a greater measure of basic research than the little now being done on industry problems. In my opinion, we must re-establish a basic research program, divorce it from practical problems and pressures, and have the confidence that the investment will pay off in the future.

The question of where or who will do basic research leads again to education—to the schools and to the non-profit agencies. Nowhere is there better climate for basic research than in the schools and in state and federally supported agencies. Yet the trend in the lumber field seems to be in the

direction of such agencies having to promote product development and applied research to justify their existence. This is not meant to criticize practical research but only to say that more emphasis must be placed on basic professional work, even at the expense of having to find some other source for solutions to the practical problem. There is a place for the student's studies leading to advance degrees, much of which encompasses basic studies, but a program of studies by professionals offers the best opportunity for significant findings.

Attracting Technical Men

It is one thing to find the support for research and another to find the men capable of the task. We are strongest in development and so-called applied research because that is what most firms have been interested in. The *brain* who finds the clue to the answer to major industry problems may be with us today but the odds are that he is not. It is simply a matter of statistics to say that if we create the atmosphere to attract enough technical people we will find among each group those inclined to different phases of research, to manufacture, to marketing, to technical service, and to design; from which will come the answers. But the competition is keen. The basic problem is to attract the kind of men needed to or from our schools. If it is true that our schools are not turning out enough technical men for the industry, then either the image of the industry is poor or there has been almost complete lack of selling the industry to young men.

Much attention is being given to this problem, and good progress is being made, though attention seems to be concerned with our schools of forestry. Being an outsider by training, I often wonder why we specialize in forest products. Why is the lumber industry so different that it can not use a greater proportion of graduates of the basic courses of study? By relying on specialists, we greatly narrow the field of potential employees, and we place the young man in the position of having to choose his field of work before he may be ready to do so. Why should a young man of the type the industry needs, choose a course of study which tends to bind him to one industry rather than choosing a course, such as various types of engineering, chemistry, or physics, where upon graduation he has many fields to choose from, and can relatively easily switch from one to the other. Obviously, there are so many facets to the lumber industry that a man need not feel confined, but cannot more use be made of those not specifically trained for the lumber industry.

The trend has been toward more general training in many fields and the solution to the technical manpower need of the lumber industry may lie in that direction, particularly for the larger firms. Smaller firms may satisfy their needs by greater use of consultants and by farming out studies and research for which they cannot justify employing a permanent staff.

Each of us has a stake in attracting men to the industry, whether they serve as employees, consultants, or in industry technical service organizations. The task is one of the lumber industry, generally, selling itself in competition with other industries, either in getting the young man into the right course or in bidding for the technical graduate.

TECO Educational Work

The educational activities of the Timber Engineering Company are worthy of review since those activities have been instrumental in developing an almost entirely new system of construction and in reclaiming what was 25 years ago a diminishing lumber market. Being dedicated to trade promotion in behalf of the lumber industry, Teco's position is unique and its activities in the line of education could not necessarily serve as a guide for the normal commercial operation. The types of activity, however, are those which any firm can participate in to some degree. The collective strength of many firms, each doing a small part, would soon be reflected in a better climate for lumber use, and a better acceptance or even preference by the consumer and by home and building owners.

No private firm in the lumber industry has spent as great a proportion of its income on promotional and educational effort than has Teco, and Teco *is* a private firm, existing only by virtue of the products and services which it sells. Its activities cover the full range from general promotion of lumber to the more specific activities relating to education efforts in behalf of lumber. We have been more fortunate than most in that Teco products are largely technical in nature. Thus our long range promotion of necessity includes cooperation with the schools to acquaint the future builders, designers, and specifiers with the advantages of Teco products and the advantages offered by lumber construction using those products.

For 18 years, Teco has provided free supplies of literature to college and universities offering courses relating to lumber and its use; on the average 10,000 copies have been distributed yearly. We have gone beyond our own literature and often supplied free-of-charge technical literature on lumber purchased from other sources. We have made available slides and motion pictures for college use, as well as for all types of group meetings.

One recent example of educational effort for the industry was the organization and preparation, with the cooperation of an outstanding group of technical men from the lumber industry, of the "Timber Design and Construction Handbook" published a few years ago by F. W. Dodge Corporation. That project alone was the equivalent of several men's full time effort for more than a year. By making available under one cover all of the basic information essential for ordinary timber design, the job of designing in timber was greatly simplified, particularly for those infrequently working with it. The very existence of a Handbook of this type does much to enhance the reputation of timber construction among architects and engineers. This type of educational activity serves a two-fold purpose; that of assisting the professional architect or engineer and, perhaps even more important, that of encouraging and simplifying training of future designers or users of wood, those who will have an important voice in determining tomorrow's lumber market.

Until recently, Teco's education activities were directed primarily toward architects and engineers and those responsible for heavy construction, a market that had largely been lost. The problem was one of re-educating these people to the advantages of wood, and the most effective method was found to be that of typical designs. We must face the fact that today's architect or engineer has little chance to specialize and is accustomed to considerable help from various material suppliers. If a job can be made simpler by direct technical assistance or by typical designs, he will be much more inclined to make use of lumber than if he must start from scratch on his own. The timber fabricating industry has played an increasingly important role in heavy construction in recent years, building on the basic work started by Teco and adding their own ideas and developments, so that today the heavy field is healthier for lumber than it was 25 years ago.

A New Field

In the past 10 years, there has been a gradual change in emphasis at Teco from the heavy to the light field, and from technical people to the builders and general users of lumber. This re-

flected the growing recognition of the importance of the volume lumber market in light construction, such as housing and a realization that the application of improved construction practice to this field, would pay even more handsome dividends than had previously been found in the heavy construction field. Here again typical designs have proved the best tool. But coupled with design work, has been promotional and educational work with the individual home builders and retailers to show them how the principles of engineered construction and engineered connections will work to advantage in the carpenter-built field. Of all the changes in home construction method introduced since World War II, none has contributed as much in economy of construction as the clear-span, trussed-rafter system of roof construction pioneered by Teco. Other changes in home framing methods have not essentially altered the construction systems from that which has been used for the past 50 years; most changes have merely moved the assembly processes from the field into the shop.

The Housing Challenge

Here, in housing, is the greatest challenge the lumber industry has ever faced. Here is the market the competitors are attacking. The problem is the medium and low cost housing. Call it an educational problem, a manufacture or distribution problem, a research problem—it combines them all; but if the industry does not help find the answer the competition will.

Perhaps we or the builders are not doing as good a job with lumber as we already know how to do, and we may now have the "tools" for the immediate problem, but planning must start NOW for the market 5 or 10 years hence. The answers without question will be largely technical changes, and "technical" means education. If the same lumber is put together essentially the same way 5 or 10 years from now as today, it will be only to build a luxury cadillac-class home. The volume lumber market in medium and low cost housing is demanding a better answer than we have today. The lumber industry must supply the answer—no one else will do the job for us.

The Industry Role

The industry must look beyond the present, shake loose from the time-honored opinions as to what can be done. Each man and each firm should afford a small percentage of investment in education—educational effort for and in cooperation with the schools, in behalf of ultimate better manufacture and improved products, in selling or educating the designers and users of our products.

Taking advantage of the technical opportunities now in sight, opportunities conceived, nurtured and born of education, the wood industries can demonstrate that the age of miracles applies to wood as well as to other basic materials.

Progress doesn't just happen.

The opportunity exists—it is not given—it must be taken.

Dimensional Stabilization of Wood with Aldehydes & Related Compounds[1]

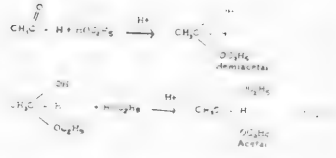
J. W. Weaver, J. F. Nielson, and I. S. Goldstein

Research Department, Koppers Co., Inc., Verona, Pa.

NATIVE CELLULOSE, AS IT EXISTS in plants and animals, consists of long chains of glucose units joined by uniform glycosidic bonds. The chains are arranged in strands or bundles containing definite intermittent "crystalline" regions in which the well oriented portions of the chains are held together by strong interchain hydrogen bonds. Between these "crystallites" are regions which may be called "amorphous", in which the chains are tangled and so poorly oriented that few of these strong interchain bonds exist. In these amorphous regions some of the spaces between the chains are large enough to permit the entry of relatively large molecules A small molecule such as water, can easily enter this amorphous region and attach itself to one or two of the cellulosic hydroxyl groups by means of hydrogen bonds. In so doing it pries the chains apart to allow the entry of more water into the amorphous region. This prying apart of the chains makes the cellulose "swell".

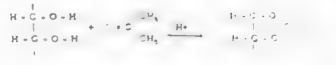
If we could form some kind of strong bond between adjacent chains in these amorphous regions, the entry of water, and the attendant swelling would be prevented. Only a few such links should be needed and the process might be very economical. The prevention of swelling in cotton and wood by treatment with a small amount of formaldehyde is well known (13, 16, 19, 22).[2]

Under the catalytic influence of the H+ ion and in the absence of free water, typical aldehydes will react with alcohols to form first moderately stable derivatives (hemiacetals) which react further to yield stable compounds known as acetals.



This formation is reversible, and acetals are readily hydrolyzed with water and a mineral acid catalyst.

In a similar manner, carbohydrates with adjacent hydroxyl groups will react with acetone, benzaldehyde or furfural to form cyclic derivatives (12):



Since cellulose is a carbohydrate it should, and does, react with some aldehydes to form these acetal derivatives.

For over 50 years cotton and rayon fabrics have been treated with formaldehyde to impart water- and crease-resistance, and the mechanisms of the chemical reactions involved have been extensively studied 13,

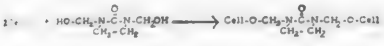
The Authors: J. W. Weaver holds a Ph.D. from Tulane, formerly senior chemist at Koppers, he is now with Cone Mills Corp., Greensboro, N. C.; J. F. Nielson has a degree in chemistry from the U. of Pittsburgh, he has been with Koppers for 7 years; I. S. Goldstein, Manager, Wood Chemistry Group, Koppers Research Center, holds a Ph.D. from Harvard.

[1] A contributed paper received July 9, 1959.

[2] Numbers in parentheses refer to Literature Cited at the end of this report.

). Stamm and Tarkow (16, 19) have thoroughly investigated the treatment of wood with formaldehyde and have reported good stabilization or antishrink efficiencies, but also noted losses in toughness.

Recently textile researchers have turned to other aldehydes and related compounds for the treatment of cotton and rayon with remarkable success. The new market for "wash-and-wear" fabrics is a result of the reaction of amido compounds, chiefly N,N'-dimethylol-ethyleneurea with cellulose. The reagent cross-links two adjoining cellulose chains and stabilizes the dimensions of the fabric (1,21). For-



mals or acetals of long-chain compounds are claimed to stabilize cellulosic fabrics similarly by cross-linking through a kind of transetherification (5,7). Other workers have treated cotton with dialdehydes, i.e. compounds containing two aldehyde groups, such as glyoxal (3,4), glutaraldehyde (4,15) and alpha-hydroxyadipaldehyde (4).

In Japan, much emphasis has been placed on fibers from polyvinyl alcohol, which have been cross-linked with long-chain aliphatic aldehydes such as nonyl aldehyde (10) and substituted aromatic aldehydes (17, 18).

Starch, closely related in structure to cellulose, has been treated with chloral (trichloroacetaldehyde) to form insoluble hemiacetals and acetals (8,14).

A survey of the literature revealed only one reference to the treatment of wood with these or related compounds. Kenaga (6) stabilized the dimensions of pine by treating with solutions of phthalaldehydic acid. Because of this obvious lack of information we undertook the investigations described in this paper.

Materials and Methods

The aldehydes and related compounds were applied to the wood, when possible, from aqueous solutions containing the catalyst. When the aldehydes were not water-soluble they were applied from solution in dioxane or another solvent. When such solvents were used, it was sometimes necessary to impregnate the wood first with an aqueous solution of the catalyst and dry before impregnating with the aldehyde.

All impregnations were full-cell in a laboratory treating cylinder with a period at 27–28 inches (Hg) of vacuum followed by a pressure period at 175 psi.

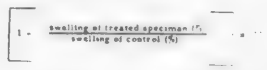
Fig. 1.—Impregnated wafers were weighed to the nearest 0.01 gram and measured to the nearest 0.001 inch by means of a jig and dial gauge.

Wood specimens were wafers of ponderosa pine cut ¼ inch longitudinally, 1¼ inches radially and 9¾ inches tangentially.

The impregnated wafers were heated in circulating ovens for various periods of time, after which they were leached in several changes of solvent or in running water for several days. They were then dried overnight at 105° C before weighing to the nearest 0.01 gram and measuring to the nearest 0.001 inch by means of a jig and dial gauge. (Fig. 1) These are called the "cured" weights and lengths. The cured wafers were then open stacked in a room conditioned at 80° F and 70 percent relative humidity until they had come to equilibrium, after which the "equilibrated" weights and lengths were determined.

Sixteen aldehydes or related compounds were investigated as possible cross-linking reagents for the cellulose in whole wood, with the thought that a few crosslinks would reduce the swelling of wood caused by adsorption of water. Results were negative under conditions used and none of the aldehydes formed stable cross-links.

The "dimensional stabilization efficiencies" or the "percent reductions in swelling", which are synonymous, were calculated by:



Treatment with Acetals and Formals: Dimethylol-ethyleneurea, mentioned above, is commercially available from many sources. One such source markets this material as a 50 percent aqueous solution. This solution was diluted with distilled water to contain 25 percent active ingredient, and was used to impregnate the test wafers. In most cases the required catalyst was added to the solution before impregnation. The impregnated wafers were cured for 2 hours at 130° C and then dried overnight at 105° C. They were then leached in running water, dried and measured. The equilibrated data were collected as described above and the stabilization efficiencies were calculated. The results given in Table 1 show that fairly low efficiencies were obtained with moderate increases in weight. This ratio would point to a bulking of the wood rather than a cross-linking, since this latter process is known to produce high efficiencies with relatively little increase in weight (16, 19). This speculation is further justified by the high permanent swelling (ca. 3 percent) imparted to the wood by the treatment. Evidently, under the conditions of our tests, dimethylol-ethyleneurea is not very effective in stabilizing the dimensions of ponderosa pine.

Other compounds used for the treatment of cotton cloth are said to

TABLE 1

THE DIMENSIONAL STABILITY OF PINE TREATED WITH 2½% DIMETHYLOL-ETHYLENEUREA

Catalyst	Conc. %(1)	Observed Wt. Gain, %	Stabilization Efficiency, %
None	----	15	24
Sulfuric acid	0.25	23	17
Zinc chloride	1.25	21	24
Zinc chloride	2.50	19	22
Magnesium chloride	1.25	20	20
Magnesium chloride	2.50	16	18
Ammonium chloride	1.25	19	36
Ammonium chloride	2.50	15	40
Diammonium phosphate	1.25	14	28

(1) Percent of solution weight

TABLE 2

THE DIMENSIONAL STABILITY OF PINE TREATED WITH A GLYCOL ACETAL (1)

Conc.(2) of Acetal, %	Catalyst	Catalyst Conc. % (2)	Observed Weight Gain, %	Stabilization Efficiency
25	Magnesium chloride	12.5	5	2
20	Magnesium chloride	10.0	4	1
20	Magnesium chloride	20.0	1	-6
20	Sulfuric acid(3)	1.0	-1	57
15	Magnesium chloride	7.5	3	0
10	Zinc chloride	1.0	7	10

(1) "Quaker Reactant SC"

(2) Percent of solution weight

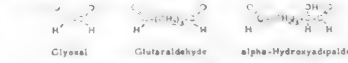
(3) Sample impregnated with 1% sulfuric acid and air-dried before treatment with acetal.

cross link cellulose in accordance with the following generalized reaction.

One of these compounds, "Quaker Reactant SC" was used to treat pine dimension wafers in accordance with the conditions listed in Table 2. The wafers were impregnated full-cell with aqueous solutions containing catalysts, drained, and cured for 16 hours at 125° C, after which they were leached in running water for 2 days, dried, measured and weighed. Dimensional stabilization efficiencies which are also shown in Table 2, were determined after equilibration with an atmosphere at 80° F and 70 percent relative humidity. Apparently this compound reacts with wood only when catalyzed with a strong acid such as sulfuric acid, which unfortunately damages the wood. The high stabilization efficiency achieved with a slight weight loss (due to degradation of the wood) is quite likely the result of cross-links established between cellulose chains, possibly by formaldehyde split off from the reagent. However, because of the degradation, the process is not applicable to the dimensional stabilization of wood.

Treatment with Dialdehydes: The reactions between cellulose and dialdehydes may yield several products, some of which are cross-linked.

The attachment of two celluloses to the same carbon atom of the reagent would give a cross-link almost identical with that resulting from treatment with formaldehyde, but the process would have the advantages of a higher boiling reagent with two functional groups instead of one. Three of these dialdehydes are available in commercial quantities for 20 to 25 cents for a pound of 25 to 30 percent solution. Their structures are shown below.



Glyoxal Glutaraldehyde alpha-Hydroxyadipaldehyde

Pine dimension wafers were impregnated full-cell with aqueous solutions of various concentrations of these dialdehydes containing catalysts, and cured in the oven at 120°–125° C for various periods of time. They were then washed, dried, weighed and measured. In order to make fair comparisons of catalyst activities with the three dialdehydes, catalyst/aldehyde proportions were calculated on a molar basis. Thus 5 mole percent of zinc chloride means that 5 mole weights of zinc chloride were used for each 100 mole weights of the individual aldehyde.

Table 3 shows the yields obtained in wood with the three aldehydes catalyzed by four different catalysts. The pine wafers were impregnated with aqueous 10 percent solutions of the aldehydes containing the indicated concentration of catalyst, and were cured overnight at 125° C before washing and drying. To obtain the "yield" the observed increase in weight after curing and leaching, was divided by the amount of dialdehyde picked up by the wood.

From these data, 10 mole percent of zinc chloride was chosen as a standard catalyst for further study.

Twenty-four pine dimension wafers were impregnated with a 10 percent solution of glyoxal containing 10 mole percent of zinc chloride. The wafers were then cured in pairs for 4,8 and 24 hours at 80°, 100° and 120° C. The cured samples were leached, dried and weighed. Yields were calculated as before, and are plotted in Figure 2 which shows the relationship between cure time and yield at the three temperatures. From these curves, 4 hours at 120° C was selected as a standard cure for a study of the three available dialdehydes.

The solutions supplied by the manufacturer contained 25 percent glutaraldehyde, 30 percent glyoxal and 25 percent alpha-hydroxyadipaldehyde. Inspection of Table 3 will show that alpha-hydroxyadipaldehyde and glutaraldehyde gave much lower yields than glyoxal. Portions of the available solution of glutaraldehyde were evaporated under vacuum at 70° C to give solutions containing about 31 percent and 37 percent. Concentration was stopped at 37 percent because the solution became cloudy. Similar treatment of the alpha-hydroxyadipaldehyde gave solutions containing about 38 percent and 60 percent by weight. These concentrated solutions and diluted portions of the original solutions were used to treat pine dimension wafers as described above. Each solution contained 10 mole percent of

TABLE 3

YIELD(1) OF REACTION PRODUCT IN PINE IMPREGNATED WITH 10% SOLUTIONS OF THREE DIALDEHYDES AND CURED AT 125°C

	Mole % Catalyst						
	$ZnCl_2$				$MgCl_2$	PDMC(2)	PC(3)
Aldehyde	5	10	25	50	10	10	10
Glyoxal	84	89	79	62	52	84	42
Glutaraldehyde	29	36	38	34	32	--	20
alpha-Hydroxyadipaldehyde	59	55	62	58	47	--	37

(1) Yield = Observed weight gain after curing divided by the weight of aldehyde picked up by the wood in the impregnation

(2) PDMC = Phenyldimethylammonium chloride

(3) PC = Pyridinium chloride

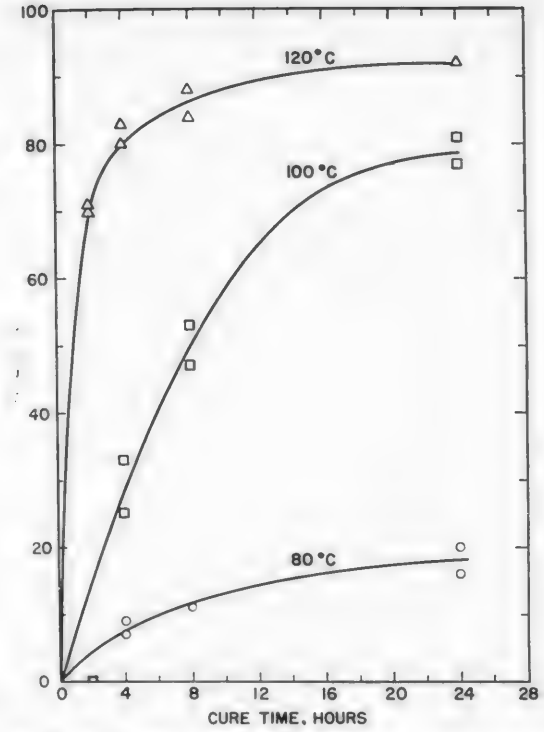


Fig. 2.—The relationship between yield of permanently fixed glyoxal in pine dimension wafers and time of cure at three temperatures. The solutions contained 10 mole percent of zinc chloride as catalyst.

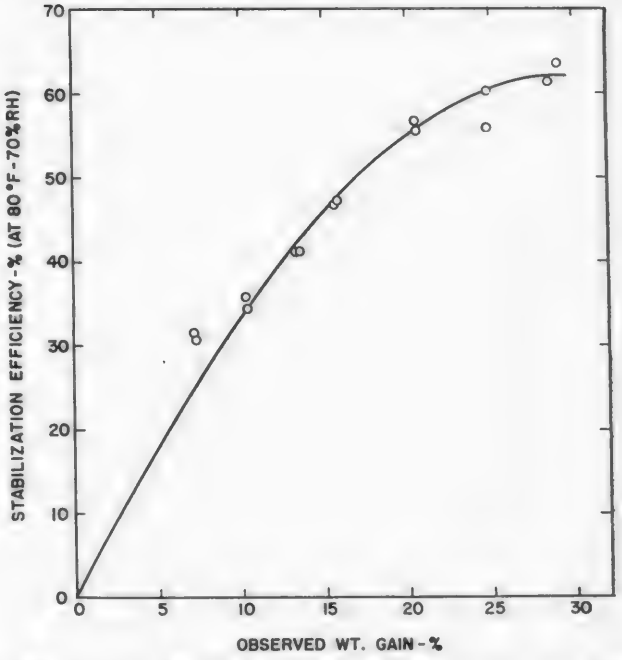


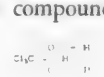
Fig. 4.—The relationship between the observed weight gains and the stabilization efficiencies calculated for pine dimension wafers treated with aqueous solutions of chloral hydrate and cured without catalyst.

zinc chloride as a catalyst. The impregnated wafers were cured for 4 hours at 120° C, washed, dried, weighed and measured and allowed to come to equilibrium with an atmosphere at 80° F and 70 percent relative humidity. The stabilization efficiencies were calculated and plotted against the observed weight gain of the sample. This relationship is shown in Figure 3.

Again, the high weight gains required for reasonable stabilization efficiencies indicate the absence of cross-linking and point to a bulking of the wood.

The maximum efficiency appears to be in the neighborhood of 50 percent, and although an effect of this size is appreciable, it is by no means comparable to the 70 percent obtained with other treatments such as acetylation (20), cyanoethylation or treatment with beta-propiolactone (2).

Treatment with Miscellaneous Aldehydes: The electron-binding capacity of the three chlorine atoms in chloral, Cl_3C–CHO (trichloroacetaldehyde) alters the nature of the bonds to such an extent that this compound easily forms acetals, and is, in fact, marketed as the stable chloral hydrate, an acetal-like compound with water:



Pine dimension wafers were treated fully cell with aqueous solutions of chloral hydrate of various concentrations up to 40 percent. No catalyst was required to give significant gains in weight. The impregnated samples were heated overnight at 105° C and handled as usual. Leaching with water after curing removed all of the impregnant, so leaching was omitted for the samples described below.

The dimensional stabilization efficiencies obtained with pine samples which had not been leached after curing are shown in Figure 4. In view of the very mild conditions employed, the reductions in swelling obtained with this treatment are very interesting. However, the product is unstable. When the treated wafers were stored in the room conditioned at 80° F and 70 percent relative humidity the retention of chloral gradually diminished until, after 15 weeks, the apparent weight gains were negligible and the samples swelled as much as untreated controls.

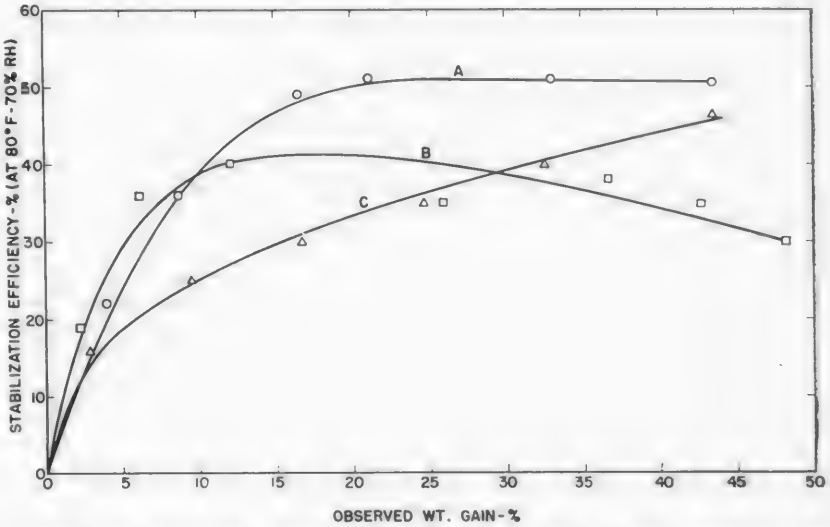


Fig. 3.—The relationship between the observed weight gains and the stabilization efficiencies calculated for pine dimension wafers treated with: A = glutaraldehyde, B = glyoxal and C = alpha-hydroxyadipaldehyde. The solutions contained 10 mole percent of zinc chloride and the wafers were cured at 120° C for four hours.

Addition of zinc chloride catalyst to the treating solution did not prevent the leaching of the chloral after curing. Extending the time of cure did not reduce the apparent weight gain, nor did it improve the permanence of the treatment.

The foregoing observations suggest a mechanism. Since chloral easily forms a hydrate, it also easily forms hemiacetals or acetals with the cellulose, probably by transfer between the water of hydration and the cellulosic hydroxyl groups. The heat applied during curing (105°C) rapidly vaporizes this water of hydration and drives the reaction to completion. The chloral molecules which have combined with the cellulose bulk the wood and reduce the shrinkage, thus stabilizing the dimensions. But the reaction is reversible. In the presence of an excess of water, such as in the leach employed in our procedure, the chloral is easily replaced by water. In a moist atmosphere at room temperature this replacement would be much slower, but it would proceed. Since the chloral hydrate has a small vapor pressure, about 15 mm. at room temperature, it will slowly evaporate and the reaction will proceed to completion in this reverse direction.

Prior to the issue of the Kenaga patent (6) some experiments were carried out with phthalaldehydic acid, which may be represented by:

Pine dimension wafers were impregnated with solutions of this compound in acetone containing p-toluenesulfonic acid as a catalyst, and then cured overnight in an oven at 105°C. The treated wafers had apparent weight gains up to 34 percent, but the maximum stabilization efficiency attained was only 40 percent. Kenaga (6) claims much better results with other catalysts.

Acrolein, an unsaturated aldehyde, is said to react with alcohols in the presence of an acid catalyst to form acetals (9). Pine dimension wafers were impregnated with acrolein and with 50 percent acrolein in dioxane. Both treatments were employed uncatalyzed as well as catalyzed with 0.2 percent p-toluenesulfonic acid. The impregnated samples were heated at 50°C for 4 hours while submerged, then drained and cured overnight in an oven at 105°C. They were then studied in the manner already described. The uncatalyzed treatments gave no significant changes in weight or degree of swelling while those containing the acid catalyst gave observed weight gains of 7.1 percent and 1.1 percent with reductions of swelling of only about 9 percent.

Several other aldehydes were screened as possible stabilizers for wood in the following manner. Pine wafers were impregnated with a 5 percent solution of zinc chloride in water, and allowed to air dry. These catalyzed wafers were then impregnated with 25 percent solutions of the aldehydes in dioxane, drained and then cured overnight in an oven at 120°C. The treated samples were leached, dried and studied as previously described. Because of the degradation brought about by the zinc chloride at this elevated temperature all of the treatments caused apparent decreases in weight. The highest dimensional stabilization efficiency observed was 40 percent. The aldehydes investigated were:

Chloroacetaldehyde
Heptaldehyde
Furfural
Benzaldehyde
o-Chlorobenzaldehyde
p-Chlorobenzaldehyde
p-Hydroxybenzaldehyde
m-Nitrobenzaldehyde

Summary and Conclusions

Sixteen aldehydes or closely related compounds were investigated as possible cross-linking reagents for the cellulose in whole wood. It was speculated that a relatively few cross-links would cause significant reductions in the swelling of wood ordinarily brought about by adsorption of water from a moist atmosphere.

The dialdehydes glyoxal, glutaraldehyde and alpha-hydroxyadipaldehyde, when catalyzed with strong acids or acid salts, gave substantial reaction with ponderosa pine, but the resulting reductions in swelling were not sufficient to justify further study.

Chloral hydrate reacts easily with wood to give products having good dimensional stability. Unfortunately, the chloral is rapidly removed by liquid water, and slowly disappears in moist atmosphere while the wood recovers its original capacity for moisture adsorption and subsequent swelling.

We may conclude that under our experimental conditions none of the aldehydes formed stable cross-links. It is possible that under different conditions, or perhaps with other aldehydes such links might be formed in wood.

Literature Cited

1. Cooke, T. F., Roth, P. B., Salsbury, J. M., Switlyk, G. and vanLoo, W. J. 1957. Comparison of wrinkle-resistant finishes for cotton. Textile Research J. *27*, 150–165.
2. Goldstein, I. S., Dreher, W. A., Jeroski, E. B., Nielson, J. F., Oberley, W. J. and Weaver, J. W. 1959. Wood processing: Inhibiting against swelling and decay. Ind. Eng. Chem. 51:1313–1317.
3. Head, F. S. H. 1958. The reactions of cellulose with glyoxal. J. Text. Inst. *49*, T345–T356.
4. Horowitz, M. D. and Conlon, I. E. 1958. Dialdehydes as cotton cross-linkers. Textile Research J. *28*, 257–262.
5. Irvine, J. B. and Kress, B. H. 1958. Acetal cellulose reactants. Textile Research J. *28*, 148–158.
6. Kenaga, D. L. 1957. Stabilized wood and a method for its production. U.S. Pat. 2,811,470.
7. Kress, B. H. 1959. Reactions of formals and polyformals with cellulose. Amer. Dyestuff Reptr. *48*, (4) 33–36.
8. Meyer, K. H. and Feng, C. P. 1932. Über hemiacetale des chlorals mit amylose. Ber. *85*, 590–592.
9. Myers, D. R., Magerlein, B. J. and Staffen, G. W. 1954. Process of producing acrolein acetals. U.S. Pat. 2,678,950.
10. Nakamura, N. 1957. Acetalization of polyvinyl alcohol. J. Soc. Text. Cellulose Ind. Japan *13*, 518–522, 580–582. Abst. in J. Soc. Dyers and Colourists *74* 325 (1958).
11. Pfeffer, E. C. Jr. and Epelbei J. 1948. Method of stabilizing against shrinkage textile materials of regenerated cellulose. U.S. Pat. 2,436,07
12. Pigman, W. 1957. The Carbohydrates. pp. 229–240. Academic Press, New York.
13. Roff, W. J. 1958. A review of the literature relating to the interaction of cellulose and formaldehyde. J. Text. Inst. *49*, T646–T663.
14. Sato, N. 1952. Starch paste. Japanese Pat. 3089, Abst. in Chem. Abst. *47*, 7246 (1953).
15. Schroeder, C. W. 1958. Treatment of textile materials and composition therefor. U.S. Pat. 2,826,514.
16. Stamm, A. J. 1959. Dimensional stabilization of wood by thermal reactions and formaldehyde cross-linking. Tappi *42*, 39–44.
17. Tanabe, K. and Matsubayashi, K. 1957. Acetalization of polyvinyl alcohol fibers with hydroxyaromatic aldehydes. J. Soc. Text. Cellulose Ind. Japan *13*, 623–628. Abst. in J. Soc. Dyers and Colourists *74*, 322 (1958).
18. Tanabe, K. and Ohno, K. 1956. Acetalization of polyvinyl alcohol fibers with higher aldehydes. Sen-i-Gakkaishi *12*, 258–264; 534–548. Abst. in Chem. Abst. *51*, 17172 (1957).
19. Tarkow, H. and Stamm, A. J. 1953. Effect of formaldehyde treatments upon the dimensional stabilization of wood. J. Forest Products Res. Soc. *3*, 3, 33–37.
20. Tarkow, H., Stamm, A. J. and Erickson, E. C. O. 1950. Acetylated wood. Forest Products Laboratory Report No. 1953, revised. Forest Products Research Laboratory, Madison, Wis.
21. Walter, H. C., Buxbaum, J. K. and Green, L. Q. 1957. The mechanism of crease-resistance development on cellulosic fabrics treated with dimethylol ethylene urea. Textile Research J. *27*, 146–149.
22. Woo, H. K., Dusenbury, J. H. and Dillon, J. H. 1956. The reaction of formaldehyde with cellulosic fibers. Text. Research J. *26*, 746–783.

EFFECT OF WETTABILITY OF WOOD ON . . .

Glue-Line Behavior of Two Urea Resins[1,2]

H. G. FREEMAN and F. F. WANGAARD Yale University, School of Forestry

Fig. 1.—Typical variation about glue-joint shear strength—assembly time relationships for two species.

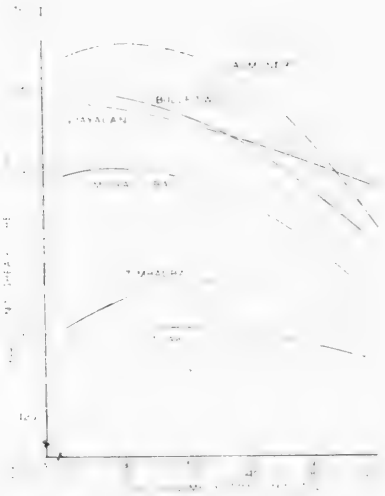


Fig. 2.—Shear strength—assembly time relationships for six species glued at room temperature with fast-setting (Glue A) and slow-setting (Glue B) urea resins.

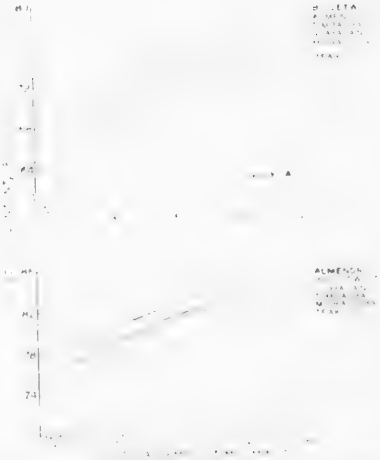
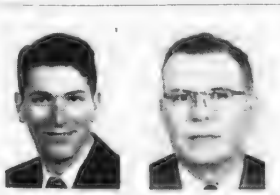


Fig. 3.—Effect of species on the solids content of spread adhesive throughout a range of closed assembly time.

IN A RECENT PAPER FREEMAN[3] demonstrated that, among other factors, the wettability of wood as determined by the contact-angle method is related to glue-bond quality. A logical explanation of this is based on the premise that wetting of the surface by an adhesive is a necessary prerequisite to bond formation. The purpose of the present study was to examine more closely the effect of the wettability of wood on glue-line behavior, particularly with respect to changes in the characteristics of the spread adhesive film during closed assembly periods. A better understanding of glue-line behavior and of the factors influencing such behavior is essential to the rational treatment of problems relating to glue-bond quality.

A close examination of the role of the wettability of wood and how it influences the interrelationships between assembly time, glue-line solids and viscosity, and glue-joint strength of the species of wood.

The general approach of this study was to glue blocks of several species selected to cover a wide range in wettability and to vary the gluing procedure only from the standpoint of employing a series of closed assembly times with each of two urea-resin adhesives. For each assembly time, tests were conducted to determine glue-line solids content and glue-line viscosity immediately prior to the application of gluing pressure. Following completion of adhesive cure, block-shear tests were conducted to determine glue-



Authors: Harlan Freeman holds a B.S. in wood technology from Minnesota and an M.F. from Yale. He was second-place winner of the 1959 Wood Award. Dr. Wangaard is in charge of instruction and research at the Yale School of Forestry.

[1] Presented at Session IX, Glues and Gluing, FPRS 14th Annual Meeting, June 7, 1960, Montreal, Canada.

[2] This research is part of a comprehensive study being conducted at the Yale School of Forestry in cooperation with the Office of Naval Research, Dept. of the Navy, under Contract Nonr 609(13), Project NR 330-001, Properties of Tropical Woods.

[3] Relation between physical and chemical properties of wood and adhesion. Harlan G. Freeman. Forest Products Journal 9:451-458. December 1959.

Table 1.—WETTABILITY, pH, AND DENSITY OF THE SIX SPECIES SELECTED FOR THE GLUING STUDY

Species	Scientific Name	Specific Gravity oven-dry volume basis	pH	Wettability: Adhesive series	Wettability: Cos. contact angle
Almendro	Coumarouna oleifera	0.94	5.1	A	0.623
				B	0.637
Bulletwood	Manilkara bidentata	1.02	5.1	A	0.585
				B	0.626
Guayacan	Tabebuia heterotricha	0.97	5.3	A	0.378
				B	0.406
Teak	Tectona grandis	0.63	5.3	A	0.051
				B	0.028
Muira-juba	Apuleia molaris	0.84	5.1	A	0.258
				B	0.232
Timbauba	Enterolobium Schomburgkii	0.95	5.3	A	0.496
				B	0.446

joint shear strength. The determination of interrelationships between assembly time, glue-line solids content and viscosity, and the glue-joint strength of a species, and clarification of the role of the wettability of wood in affecting glue-line behavior are the objectives of this work.

Experimental Procedure

The six species used in this study are listed in Table 1 together with data on such basic properties as specific gravity, pH, and wettability. These properties were shown in previous work[3] to have a significant effect upon the quality of urea-resin glue lines. The final selection of these six species was based upon the wide range of wettabilities which they exhibited and the uniformity that they showed in pH. With the exception of teak, these species lie in the range above 0.80 specific gravity in which glue-joint shear strength was shown in earlier work to be relatively independent of variation in specific gravity.

pH Determination: The end trim from gluing stock for each species was reduced to wood flour in a Mikro-Samplmill and a slurry was prepared by adding 3 grams of the wood flour to 50 grams of distilled water. After evacuating for 1 hour to facilitate leaching, the mixture was allowed to stand for 24 hours and filtered through standard filter paper. A Beckman pH meter was used to determine the pH of the filtrate. Average results of replicate determinations are shown in Table 1.

Wettability Determination: Wettability was determined using the contact-angle method previously described by Freeman.[3] This method involves lowering a flat plate of wood into distilled water, noting the curvature of the water surface as it meets the machined wood surface, and varying the inclination of the wood plate until the water surface is plane at the point of meeting the wood. The angle between the face of the advanced wood plate and the horizontal water surface is read as contact angle. Twelve wettability specimens, representative of the stock to be used with each adhesive, were tested for each species. Results are shown separately for the two sets of specimens designated as series A and B in Table 1.

Gluing Procedure: End-matched material for six assembly times was obtained from individual 6-foot sticks of clear material of each species. Stock was surfaced on a planer to a thickness of ½ inch and a light final machining cut, which was made on the day of gluing, removed less than 0.03 inch of thickness. Six pieces, 1¾ inches wide and 8¾ inches long, each to be glued at a different assembly time, as well as a short length to be spread with adhesive for determination of solids content at each assembly time, were obtained from each stick. Within a stick, assembly times were assigned on a random basis. Twelve sticks, all from the same log, provided enough material for three replications with both urea-formaldehyde resins.

Prior to machining, the stock had been conditioned in a room maintained at 72° F. and 12 percent equilibrium moisture content. Immediately following machining, the stock was returned to the same controlled humidity room where gluing and viscosity testing were conducted. Freshly mixed adhesive was double spread on each 1¾ by 8¾-inch laminated assembly at the rate of 60 pounds per 1000 square feet of glue line. Rocker-head clamps, precalibrated to give the desired pressure of 300 pounds per square inch, were used in the gluing operation.

The only experimental gluing variable was closed assembly time. Preliminary gel-time tests had shown the maximum time over which the mixed glue exhibited liquid flow, and assembly times were chosen on this basis. Adhesive A was relatively fast setting and gelled in a small container in approximately 4 hours. Glue B, in contrast, retained liquid flow characteristics for nearly twice this period. Trial spreads of adhesive on several wood surfaces in closed assembly suggested that maximum assembly time need not exceed 2 hours or 4 hours, respectively.

Table 2.—SHEAR STRENGTH, SOLIDS CONTENT, AND SLIP LOAD FOR SIX WOODS GLUED WITH TWO COLD-SETTING UREA RESINS

		Glue A, Closed Assembly Time, minutes						Glue B, Closed Assembly Time, minutes					
		10	30	50	70	90	110	20	60	100	140	180	220
Almendro	Shear Strength, psi	2904	2919	3058	2992	2266	2309	2940	3168	2789	2976	2348	1088
	Solids Content, %	66.2	68.5	74.9	76.4	78.1	80.9	76.7	82.2	83.8	83.0	84.1	85.8
	Slip Load, lbs.	1.2	1.8	5.2	111	192	780	0.7	4.2	5.6	66	282	253
Bulletwood	Shear Strength, psi	2678	2745	2247	2725	2373	2190	2889	2930	2578	2591	2442	1767
	Solids Content, %	66.7	71.1	76.5	77.7	78.5	82.2	77.5	80.9	84.6	83.4	84.1	85.1
	Slip Load, lbs.	0.9	2.9	90	185	390	540	0.5	2.4	16.1	41	257	780
Guayacan	Shear Strength, psi	2829	2736	2523	2576	2398	2395	2716	2566	2567	2694	2517	2168
	Solids Content, %	66.4	69.0	74.0	75.3	75.7	78.6	75.9	79.5	82.7	82.9	83.3	83.9
	Slip Load, lbs.	2.1	1.0	4.6	34	102	242	1.1	0.5	4.3	19.8	88	510
Teak	Shear Strength, psi	1352	1660	1745	1528	1440	1633	1704	1736	1603	1572	1549	1395
	Solids Content, %	65.0	67.6	70.6	72.0	73.4	73.8	74.7	76.8	79.3	82.2	81.0	81.6
	Slip Load, lbs.	1.2	0.9	2.7	14.2	33	105	0.2	1.0	2.0	4.5	43	208
Muira-juba	Shear Strength, psi	2309	2445	2159	2137	2033	1730	2477	2395	2333	2388	2293	983
	Solids Content, %	65.4	68.5	71.5	72.6	74.3	79.5	75.3	79.6	81.9	81.6	83.1	83.8
	Slip Load, lbs.	0.6	2.1	10.8	63	124	202	0.7	1.0	3.1	19.8	187	780
Timbauba	Shear Strength, psi	1684	1904	1749	1797	1746	1656	1507	1851	1716	1907	1834	367
	Solids Content, %	65.9	71.1	73.6	75.6	78.3	78.8	75.9	79.7	82.0	82.3	82.9	83.7
	Slip Load, lbs.	0.6	3.1	10.4	70	300	172	1.0	0.8	3.4	10.0	130	375

or these two adhesives. Below are sted the closed assembly times actu- ly used:

Adhesive	Assembly time, minutes
e A	10, 30, 50, 70, 90, 110
e B	20, 60, 100, 140, 180, 220

th adhesives were supplied as liquid ins. Glue A was very viscous and, lowing instructions of the manufac- er, 15 parts of water were added every 100 parts of resin syrup in xing. The mixing of both adhesives th appropriate cold-setting catalysts s done in full compliance with nufacturers' recommendations.

After 24 hours under pressure, the emblies were removed from the clamps and allowed to condition un- der the same 12 percent equilibrium moisture conditions for 4 more days. The assemblies were then machined into shear blocks, each assembly yield- ing four shear blocks with a shear area of 1½ by 1½ inches, and tested on a universal testing machine at a loading rate of 0.015 inch per minute to determine maximum shearing strength.

Determination of Glue-line Solids Content: Specimens from each stick were spread in the customary manner and placed together in closed assem- bly. From these a solids-content sam- ple of adhesive weighing approxi- mately 1 gram was scraped from the glue line at each assembly time and transferred to a previously weighed aluminum foil weighing dish. Each sample in its aluminum foil dish was immediately weighed on an analytical balance to 0.1 milligram. After drying for 3 hours in a forced circulation oven at 100° C., the samples were cooled over calcium chloride and re- weighed. Solids content, expressed as a percentage of the original weight of the catalyzed resin in the glue line, was determined for each species, as- sembly time, and glue. Variation in the solids content of these samples represented the effects of time and species on the dryness of the adhesive in the joint at the time of pressing.

What This Research Means

Results obtained in this study clearly demonstrate that the tolerance of individual species, as measured by decreases in glue-joint strength, to assembly times prolonged considerably beyond the optimum for the species is related to the wettability of the wood. Woods of low wettability are relatively little affected in their glue-joint quality by prolonged assembly times. Highly wettable woods show the converse.

In a more general sense, it is hoped that this study, by calling attention to the varied influences of but one property of wood on glue- line behavior, may serve to stimulate other investigations in the important area of adhesive-wood inter- relationships.

Glue-line Viscosity: An attempt was made to obtain a measure of the viscosity of the adhesive at various solids contents by drying the glue un- der vacuum, adding a catalyst, and then determining the viscosity at inter- vals corresponding to the six assembly times with a Stormer viscosimeter. Un- fortunately, the glue became too vis- cous to test with that instrument at the higher solids contents and longer as- sembly times and the method was discarded.

The possibility was suggested, how- ever, that the relative viscosity of the glue line might be determined from a mechanical test of the glued assem- bly itself. This led to the development of a so-called "slip test" which con- sisted of inserting one of the three glued assemblies for a particular as- sembly time into a testing jig so arranged that the axial shearing load required to produce slippage between the two halves of the assembly could be measured. This was accomplished by mounting the jig in an Instron ten- sile testing instrument and recording the maximum shearing load obtained when operating at a constant loading speed of 0.2 inch per minute. The test was made immediately prior to the application of gluing pressure and was conducted in the same humidity- controlled room in which the entire gluing operation was carried out. The slip test can be considered indicative of the viscosity of the adhesive in the glue line.

Results

Results of the gluing phase of the study are summarized in Table 2 which includes average values for shear strength and solids content and indi- vidual values for slip load at each of six assembly times for each adhesive and species. An analysis of variance showed that all three variables—shear strength, solids content, and slip load —were affected to a highly significant degree by species and by assembly time. The adhesive was also highly significant in its influence on slip load and solids content but not on shear strength.

The lack of a significant adhesive influence made it possible to combine the data for both adhesives in subse- quent analysis of shear strength. Curves of the type, $y = a + bx + cx^2$, were fitted by the method of least squares to the combined shear strength data for each species plotted against relative closed assembly time. Due to the difference in range of assembly

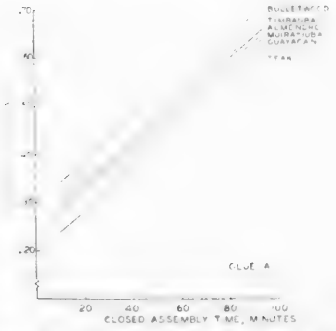


Fig. 4.—Logarithmic regression of glue- line slip load on assembly time showing the influence of species. Experimental values of slip load in pounds were converted to the form log [log (slip load x 100)] for sta- tical analysis of the relationship.

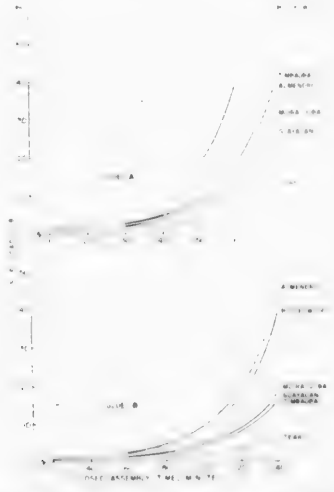


Fig. 5.—Relationships betweeen slip load (lb.) and closed assembly time for two ad- hesives showing the influence of species.

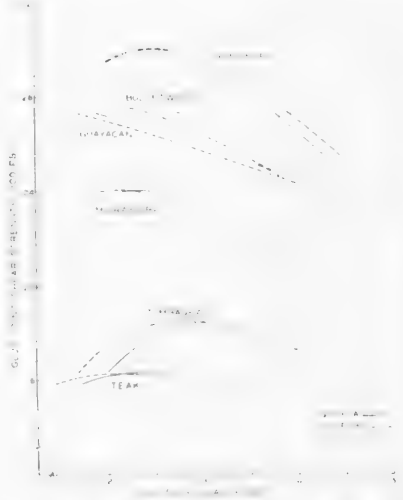


Fig. 6.—Joint shear strengths obtained with two adhesives in relation to glue-line slip load. For convenience in scale, slip load is expressed as log (slip load x 100).

times used with the two adhesives, this meant combining the data obtained at the 10-minute assembly time in the case of Glue A with the 20-minute assembly time data obtained with Glue B, and similarly combining 30-minute and 60-minute data, 50-minute and 100-minute data, etc. Figure 1, showing actual shear values plotted about two of the fitted curves, illustrates the procedure.

Smooth fitted curves of glue-joint shear strength for each species and adhesive are plotted against actual closed assembly times in Figure 2. These curves serve to emphasize the extremely different assembly-time relationships for the two adhesives as well as the individual characteristics of the six species involved in these tests. Values for optimum assembly time for each species, obtained by differentiating the quadratic equation and solving for zero slope, are shown in Table 3. Based on the attainment of maximum shear strength, optimum assembly time ranged from 10 minutes for guayacan to 56 minutes for timbauba in the case of Glue A and from 20 minutes to 113 minutes, for the same two species, in the case of Glue B. Figure 2 also reveals that individual species differed substantially in the rate at which shear strength decreased with assembly time once the optimum had been exceeded. (In passing, it might also be noted that values for percentage of wood failure in the shear blocks followed a similar trend with assembly time. At optimum assembly time, wood failure values for almendro, bulletwood, and muira-juba were high, on the order of 90 percent, and decreased sharply with prolonged assembly time to a level of 50 percent or lower. Wood failure values on the order of 60 to 70 percent at optimum assembly time were developed in teak and guayacan and the decrease at longer assembly times was moderate. In the case of timbauba, wood failure was consistently low, seldom exceeding 10 percent.)

Table 3.—OPTIMUM ASSEMBLY TIMES, GLUE-LINE VISCOSITY, AND JOINT STRENGTH VARIATION WITH ASSEMBLY TIME FOR INDIVIDUAL SPECIES

Species	Glue A		Glue B		Combined Data for Both Glues			
	Optimum ass'y time min.	Slip load at optimum ass'y time lb.	Optimum ass'y time min.	Slip load at optimum ass'y time lb.	Max. shear strength[1] psi	Min. shear strength[2] psi	Decrease in shear strength percent	Average log—log slip load lb
Almendro	33	3.0	65	2.8	3019	2115	29.9	0.47
Bulletwood	13	1.8	26	0.9	2775	2046	26.3	.48
Guayacan	10	0.8	20	0.5	2736	2314	15.4	.43
Teak	45	2.7	90	1.4	1633	1539	5.8	.38
Muira-juba	28	2.1	57	1.2	2405	1773	26.3	.41
Timbauba	56	14.5	113	6.1	1856	1469	20.8	.44

[1]At optimum ass'y. time.
[2]At 6th ass'y. time.

As mentioned previously, both species and adhesive had a significant effect on the solids content of the adhesive in the glue line after various assembly times. Quadratic equations were fitted to the solids content vs. assembly-time data by the method of least squares and accounted for nearly 90 percent of the total variation in solids content. These relationships are shown in Figure 3 in which the solids content of each adhesive is plotted against closed assembly time. Solids content of Glue B exceeded that of Glue A throughout the entire range of assembly times, but the rate of increase with assembly time was greater in the case of Glue A. With both adhesives, highest solids content was found in the case of bulletwood and almendro and the lowest in the case of teak. The remaining species showed intermediate solids-content percentages.

Slip load, a measure of the viscosity of the adhesive in the glue line, increased with increasing assembly time at a strongly accelerated rate. Analysis of variance of slip-load data that had been converted to logarithmic values showed a highly significant residual variation remaining after that portion of the variation due to a linear regression with assembly time had been removed. This was attributable in part to irregularities introduced by the data for the longest assembly time and partly to a general curvilinear trend remaining in the logarithmic data. The analysis was consequently repeated, deleting the data for the sixth assembly time, and recoding the remaining data in the form log [log (slip load × 100)]. The results, showing the effects of both species and assembly time for Glue A, are illustrated in Figure 4. The analysis indicated that the regression with assembly time was highly significant and that the differences between species means were also significant, but that the slope of the regression was essentially the same for the various species. The relationships shown in Figure 4 accounted for 91 percent of the total variation.

When transformed to slip load expressed in pounds, these relationships appear as shown in Figure 5. It is in this form that the curves for individual species take on the expected divergence with increasing assembly time. It will be noted that, as in the case of solids content, the curves for bulletwood and almendro tend to lie at the top of this family of curves and the curve for teak lies at the bottom. As indicated earlier, the effect of adhesive was highly significant and slip loads obtained with Glue A lie somewhat above those obtained with Glue B.

From Figures 2 and 5 it is possible to show the relationship between glue-joint shear strength and slip load (or viscosity of the adhesive) at the time of gluing pressure application. This was done by first converting values of slip load in Figures 5A and 5B to the form log (slip load × 100) for various assembly times. Values for joint

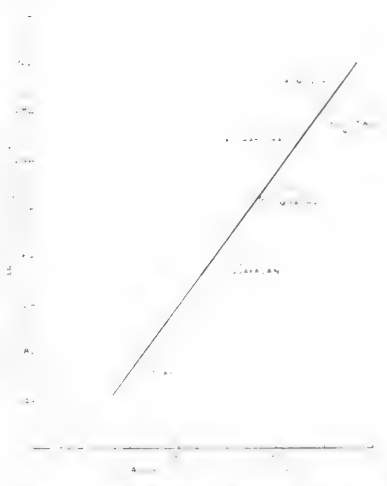


Fig. 7.—Percentage reduction in shear strength at the sixth assembly time related to the average glue-line slip load attained with individual species. Slip load is plotted as the average value of log [log (slip load x 100)].

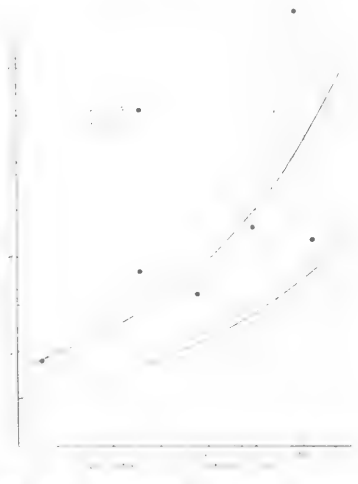


Fig. 8.—Relationship between average glue-line slip load attained with individual species and the wettability of the wood. Average values for log-log slip load, actually used in the regression analysis, have been decoded here to show slip load in pounds.

Fig. 9.—Relationship between average ds content of the spread adhesive at- ied with individual species and the wet- lity of the wood.

ear strength for the corresponding sembly times taken from Figure 2 were then plotted against these log slip-load values. Results shown in Figure 6 indicate the close similarity of the two adhesives with respect to their shear strength—slip load behavior. This is particularly evident when compared with their contrasting behavior as shown in Figure 2. The different levels of shear strength obtained with the different species are, of course, the same as shown in Figure 2.

Slip loads corresponding to maximum shear strength at optimum assembly time are included in Table 3. It is interesting to note that in five of the six species (timbauba was the exception) maximum shearing strength was attained within a relatively narrow range of slip loads. They range from 0.8 to 3.0 pounds for Glue A and from 0.5 to 2.8 pounds for Glue B out of a total range of test conditions that included maximum slip loads of several hundred pounds. Expressed in pounds per square inch, maximum shear strength in these species was associated with slip loads not exceeding 0.2 psi. The substantially higher optimum slip loads found in the case of timbauba may have been the result of an abnormal surface condition. The surface of this species tended toward a glazed condition that developed during preparatory surfacing. Although slip load at optimum assembly time is consistently somewhat lower for Glue B as compared with Glue A, it seems clear that slip load rather than assembly time brings out the common behavior of these two adhesives with regard to the variable of joint strength.

There is still another relationship hat can be detected in Figure 2. This s to do with the tolerance of indi- dual species to assembly times in cess of optimum assembly time from e standpoint of the degree to which shear strength is affected. Table 3 compares for each species the average shear strength attained with both adhesives at optimum assembly time, taken from Figure 2, with the corresponding shear strength of the species attained at the sixth assembly time (110 minutes for Glue A and 220 minutes for Glue B). The difference between these two values, expressed as a percentage of the shear strength at optimum assembly time, is also shown in Table 3 as well as the average log-log slip load value for each species corresponding to the five assembly periods that were analyzed in developing Figure 5.

The linear regression of percentage decrease in joint shear strength with the logarithmic expression for average slip load was found to be statistically significant and accounted for more than 80 percent of the total variation in the shear strength variable. The relationship is shown in Figure 7. The interpretation of these results is that over a period of extended assembly times such as those used in this study, the lowering of joint quality as indicated by reduction in joint-shear strength from the maximum for a species is minimized in the case of woods that develop relatively low slip loads. The decrease in joint quality is pronounced in those species that are characterized by the development of high slip loads over the same period of time. It is believed that under these circumstances slip load is a measure of the degree to which the glue line has dried out due to absorption of the adhesive vehicle by the wood.

Evidence to support this belief is available from an examination of the relationship between average slip load and surface wettability of these six species. Separating the data for each adhesive, average log-log values of slip load for each species were correlated with the corresponding wettability expressed as cosine of contact angle. An analysis of variance of the results showed that the regression between these two variables was highly significant and that, although the slope of the regression for the two adhesives was not different, the mean values for the two adhesives differed to a highly significant degree. Overall the relationship accounted for 85 percent of the total variance in the coded logarithmic values for slip load. The curves in Figure 8 show transformed values of slip load in pounds plotted against wettability expressed as cosine of contact angle. Increasing wettability is related to increasing average slip load with both adhesives.

A similar analysis was made of the relationship between average solids content attained in the glue line of the various species and the wettability of the species. For complete comparability, these data were limited to the first five assembly times as was the case in the treatment of the slip-load data (Figure 8). An analysis of variance showed that the linear regression between solids content and wettability was highly significant, that the difference between adhesives in the slopes of their regressions was significant, and that the difference in their mean values for solids content was also highly significant. Results are shown in Figure 9. With increasing wettability, the average solids content attained in the glue line with each adhesive increases. Comparing the two adhesives, the increase is somewhat more apparent in the case of Glue A and is probably associated with the lower original level of solids content of this adhesive at the time of spreading. The difference in solids content throughout the range of assembly times of the two adhesives was previously shown in Figure 3.

Considered together, the relationships shown in Figures 8 and 9 clearly indicate the part played by the wettability characteristic of wood in affecting moisture withdrawal from the liquid glue line during assembly. Through its influence on glue-line solids content and glue-line viscosity, wettability influences not only the condition of the adhesive associated with optimum joint strength, thereby influencing optimum assembly time, but it also influences the tolerance of the joint to the extension of assembly time beyond the optimum.

Conclusions

During the period of closed assembly prior to the application of gluing pressure, glue-line solids content and viscosity increase more rapidly in woods of high wettability than in woods of low wettability. Slip load (a measure of glue-line viscosity) at the time of pressure application has, in turn, been shown to be related to ultimate glue-joint quality. Although attained over a wide range of closed assembly times with two urea-resin adhesives, maximum glue-joint strength was found to be associated with a relatively narrow range of slip loads.

SOME MECHANICAL PROPERTIES OF

Wood Fibers in Tension

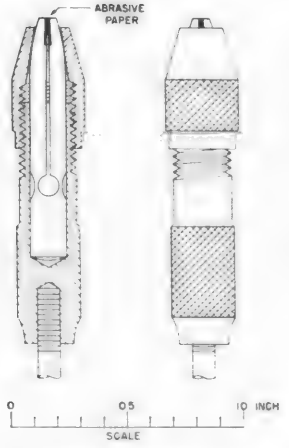


Fig. 1.—Plan and sectional view of a fiber grip.

Fig. 2.—A latewood fiber of cypress in place for testing. A common straight pin is included at the right.

B. A. JAYNE
Division of Industrial Research, Institute of Technology, Washington State University

Load-deformation properties of single fibers of wood were measured by means of an electrical–mechanical system for measuring force and deformation. Data from tests of 10 coniferous trees show vast differences between species and often between earlywood and latewood fibers of a single species.

THIS PAPER IS A SUPPLEMENT TO A previous publication (4) in which a tensile test for single wood fibers was described in addition to the stress-strain characteristics of several fibers. Since publication of the original work, an additional seven coniferous species have been examined. This report includes a brief description of the technique, but concentrates primarily on the experimental data of the ten species tested to date. The species included in the testing program were selected to provide a wide variety of the gross anatomical structures which occur in coniferous stems. It was anticipated that the fibers of these species also would be characterized by a wide range of mechanical properties and, therefore, would be representative of fiber structures occurring in native coniferous trees.

The Author: B. A. Jayne is associate wood technologist at Washington State. He holds a BSF from the University of Idaho and MF and DF degrees from Yale.

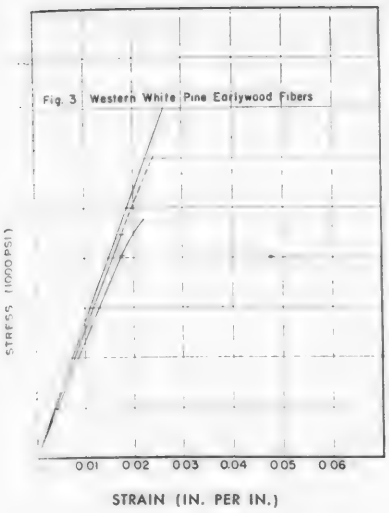
Textile fiber mechanics has been studied by a number of researchers since the early part of the 20th century. Of these investigators the work of Eyring and co-workers (2), Meredith (7), and Leaderman (5) has contributed immeasurably to a better understanding of fiber properties, particularly the influence of molecular organization on the rheologic properties of the fiber. In contrast, a fundamental approach to wood fiber rheology has been lacking, due primarily to its minute size and, in the past, the lack of suitable devices for precise measurement of its strength and deformation. Until recently, the work of Rühlemann (11), Van den Akker, *et al* (13), and Wardrop (14) stood as the existing research dealing with wood fiber mechanics. Their efforts were directed primarily toward measurement of fiber strength.

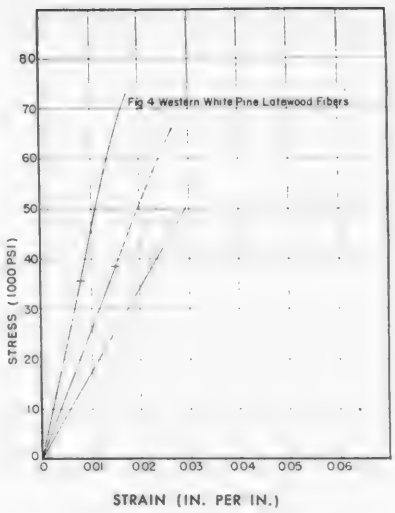
Over a period of the past 20 years, several theories of rheological behavior of various polymeric materials have been proposed. Linear viscoelastic behavior as treated by Leaderman (5) and Alfrey (1) and also the non-linear theory proposed by Eyring and co-workers (2) for textile fibers have been foremost among these. Linear viscoelastic theory has received a great deal of application for describing the stress-strain-time properties of cross-linked as well as linear amorphous polymers, particularly when confined to low stresses. It is interesting to note that only recently, Pentoney (9) demonstrated that the linear theory is applicable to studies of the rheology of wood when stresses are maintained at a low level.

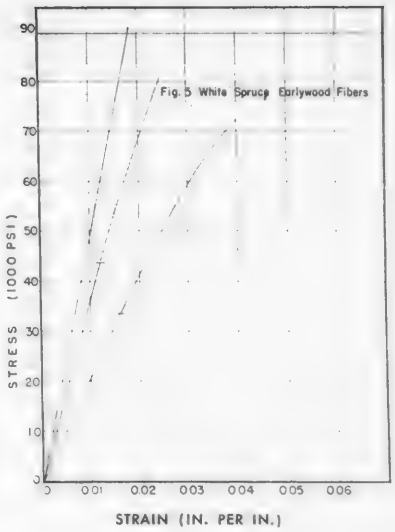
On the other hand, Eyring and co-workers (2) have observed that models possessing dashpots of Newtonian viscosity, in addition to the customary perfectly elastic springs, cannot explain adequately textile fiber stress-strain-time properties. Rather, the flow units of models proposed by these investigators are of a non-linear character in which viscosity decreases with increasing stress. These investigators have been unusually successful in describing the creep and stress-strain properties of a variety of textile fibers by using relatively simple, non-linear models.

It is highly probable that the wood fiber will behave according to one or possibly both of these theories. In general, linear viscoelastic theory is not applicable for materials of two phase structure such as wood which contain both crystalline and amorphous regions. However, as demonstrated by Pentoney (9) and a number of other researchers (3, 8, 10), wood is characterized by linear viscous damping at low levels of stress. Consequently, it is not unlikely that a stress region or low level exists for the wood fiber within which linear viscoelastic theory is applicable. Due to the structural similarity between the wood fiber and

[1] A contributed paper received March 19







many of the natural textile fibers; cotton, flax, and ramie, it is likely that linear theory will not be applicable at elevated stresses. Rather, it may be necessary to adopt an existing nonlinear theory from the literature or to synthesize a theory from experimental data.

No attempt has been made in this paper to develop or utilize an existing theory to explain the stress-strain properties of wood fibers. The objective has been to outline an experimental method and to describe in a qualitative manner the mechanical properties of fibers derived from several coniferous stems. It is not intended that the properties reported be interpreted as representative of each species studied. The data of each serve only as a first approximation of the species. It is hoped that this paper and a publication to follow[2] will provide the groundwork and incentive for future research directed toward the development of a mathematical theory of wood fiber rheology.

The mechanical properties of ten species are included in this paper. They were selected as representative of the coniferous trees native to the United States and include redwood *(Sequoia sempervirens)*, white spruce *(Picea glauca)*, Douglas-fir *(Pseudotsuga menziesii)*, white fir *(Abies concolor)*, western hemlock *(Tsuga heterophylla)*, Sitka spruce *(Picea sitchensis)*, cypress *(Taxodium distichum)*, western white pine *(Pinus monticola)*, slash pine *(Pinus caribaea)*, and western redcedar *(Thuja plicata)*. Data collected include tensile strength, proportional limit stress, Young's modulus, work to failure, and deformation at failure.

[2] A publication which describes the stress-strain response of the same species of wood fibers over an extensive range of relative humidities is now under preparation.

Experimental

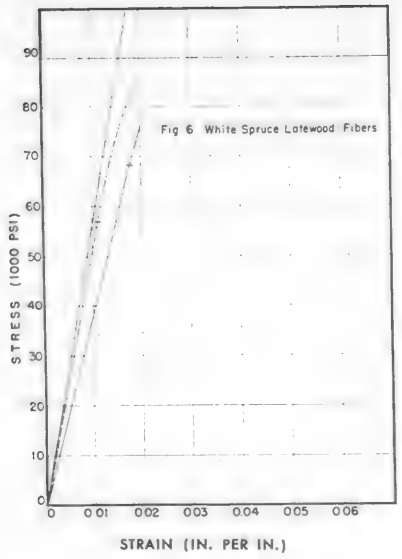
Material: Air-dried stock of the ten species, each exhibiting 10 to 20 growth rings per radial inch of cross-sectional surface, were pulped using a technique developed by Spearin and Isenberg (12) and Wise, et al (15). The method, described in detail in a previous paper on fiber mechanical properties (4), consists of chlorinating the lignin in small chips of wood through the action of sodium chlorite in a dilute acid solution. Chlorine gas, which is evolved by the sodium chlorite when the solution is brought to a temperature in the range of 80°–100° C, chlorinates the lignin in which form it is soluble in an aqueous solution. After 4 to 8 hours of treatment, during which time small amounts of sodium chlorite are added, the chips can be dispersed into their component fibers by means of vigorous agitation.

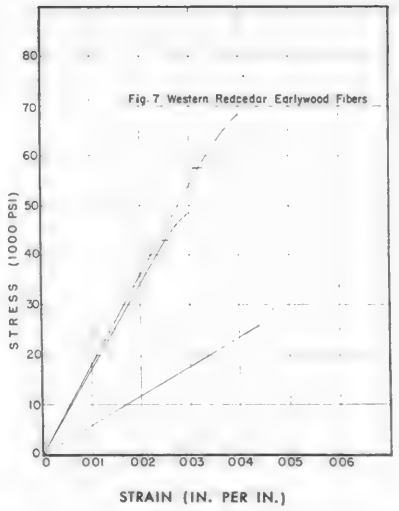
After preparation as outlined above, the pulps were rinsed thoroughly with tap water until all traces of chlorine were removed and stored in distilled water until selection for testing. Wise, *et al.* (15), report that pulps prepared in a similar manner were rich in hemicelluloses and contained from 1 to 2 percent lignin. It appears, therefore, that the technique will produce a fiber virtually free of lignin while maintaining the essential structure of the cellulosic portion of the cell wall. The chemical composition of the fibers used in this study has not been determined.

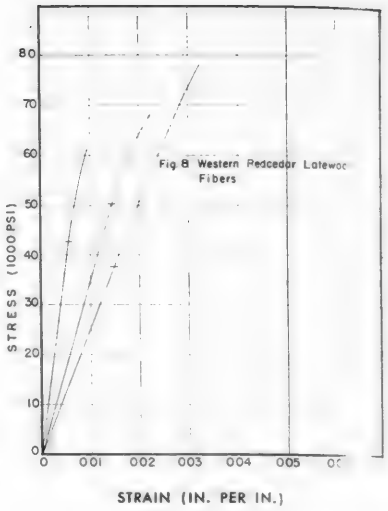
Fibers were selected for testing while observing a dilute slurry of fibers through a binocular microscope at a magnification of 30X. Using jeweler's tweezers, unbroken fibers, free of cell wall damage, were picked from the solution by grasping one end. The fibers were transferred to glass slides while still in a saturated condition. The moderate forces of adhesion that developed between fiber and glass when brought in contact were sufficient to minimize fiber twisting during drying. Later the fibers were taken directly from the slides for testing.

Testing: As pointed out previously, a dearth of instruments of sufficient accuracy to measure minute forces and deformation has stood as one of the major obstacles to studies of wood fiber mechanics. With the development of the strain-gage load cell and associated equipment in recent years, technological problems of measurement and recording of minute forces and deformation have been overcome. Nevertheless, the problem of fixing the ends of a wood fiber in order to deliver an axial tensile load remained. Tying the ends to small wire loops, as often practiced in textile fiber testing, was, of course, impossible to carry out with the wood fiber due to its short length.

After screening several techniques for fixing the fiber ends the two most promising methods were selected for intense investigation. They were: (1) bonding the ends of the fiber to small wires with an adhesive; the wire to provide a medium for gripping and (2) gripping the unmodified ends of the fiber between the faces of a vise-type grip. Early attempts resulted in the development of a system for bonding the ends of fibers to small sections of piano wire. Subsequently, the fiber and wires were placed in a testing machine, and a tensile force was applied to the fiber through the wires bonded on each end. The common variety of synthetic adhesives, which set by polymerization, were found suitable for bonding the ends of fibers. However, the extended setting time of the room-temperature-curing types un-







duly prolonged testing. When isolated to a small drop on the end of a wire, an adhesive which set by loss of solvent skimmed over before the end of the fiber could be inserted into the drop. Eastman 910, a synthetic adhesive of recent development, overcame the difficulties pointed out above. However, in a number of tests conducted with this adhesive, failures always occurred at the point of bonding. This indication of a high stress concentration in the vicinity of the bonded end, in addition to the necessity of using a variable gage length from fiber to fiber when bonding, led to the development and construction of a vise-type grip.

Scale drawings of the grip used for this study are shown in Fig. 1. A wood fiber in place for testing is pictured in Fig. 2 with a common straight pin included at the right to provide a measure of relative size. The grip is a modified machinist's pin vise in which the normal four-pronged member has been replaced by a two-pronged member, the recessed faces of which were covered with No. 400A silicon carbide finishing paper. The facing not only acted as a cushion to cover the metal faces of the grips and prevent tearing of the fiber, but also developed sufficient frictional resistance to eliminate slippage of the fiber during application of load.

Testing was carried out in an Instron testing machine using a Type-A load cell. Initially each fiber was centered in the upper grip; the grip and fiber were transferred to the testing machine and centered; and the fiber was fixed in the lower grip leaving 0.1 inch between grips. The initial gage length of 0.1 inch insured the protrusion of at least 0.03 inch of the fiber within the jaws of each grip. The load-deformation relationship of each fiber was plotted automatically using a deformation rate of 0.005 inch per minute. The electro-mechanical recording system of the Instron plotted both axes of the curves to an accuracy of ± 1 percent.

Measurement of Fiber Cross-sectional Area: A number of optical schemes for measuring the cross-sectional area of the fiber were explored in the early stages of test development. Measurements of wall thicknesses on transverse microtome sections indicated considerable variation from fiber to fiber within both early- and latewood. This observation coupled with the fact that fibers of a particular species or type varied considerably in mechanical properties pointed to the need for a cross-section measurement of each fiber. Attempts to measure the wall thickness of a single fiber by viewing a tangential or radial surface demonstrated that, although a fiber may appear to be of uniform cross-sectional dimensions, close examination reveals moderate fluctuations of wall thickness, and tangential and radial dimensions along its length.

These exploratory steps demonstrated that the cross-sectional area of the fiber at the point of failure was required in order to calculate accurate values of tensile strength. To accomplish this, a technique was developed whereby the broken end of the fiber was viewed under high magnification. After completion of a test each fiber was glued on the edge of a 1- by 3-inch glass slide with the broken end projecting upward. Using an ordinary microscope, the end was brought into focus while viewing the fiber end-on. The fiber appeared as a dark area in the field of the microscope, and the cross-sectional area could be meas[illegible]d using a calibrated micrometer eyep[illegible]e. At a total magnification of 1000X [illegible]e cross-sectional area of each fiber [illegible]as estimated to $\pm 0.01 \times 10^{-6}$ sq[illegible]e inches.

In order that data on mecha[illegible]l properties would be based only [illegible]n the mass of cellulose it was desira[illegible]le to obtain a measurement of the cr[illegible]s-section when the fiber was in a dess[illegible]cated state. Although complete des[illegible]cation could not be attained in the laboratory, measurement of fiber cross-sectional areas was undertaken only when the indoor relative humidity was less than 5 percent. The change in area due to shrinkage occurring between 5 and 0 percent relative humidity equilibrium was computed to be of the order of approximately 0.5 percent. An experimental error of this magnitude in the computation of mechanical properties was considered inconsequential.

Results

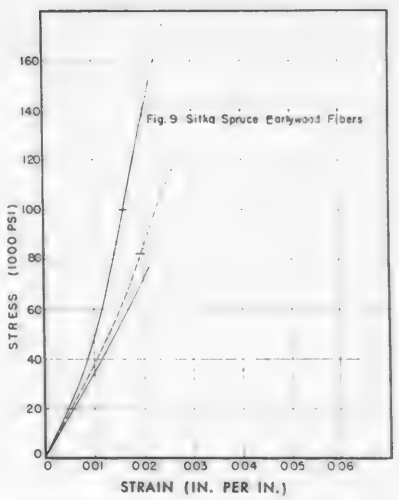
Using the load-deformation relationship, tensile strength, Young's modulus, proportional limit stress, deformation at failure, and work to failure were computed for each fiber. Tensile strength was computed as load [illegible]t failure divided by cross-sectional a[illegible] at the point of failure. The ratio stress to strain in the segment of load-deformation plot below the p[illegible]portional limit was taken as Youn[illegible] modulus. The cross-sectional area the fiber at the point of failure [illegible] used for calculation of the modul[illegible] Since it is likely that the area at t[illegible] point is or approaches the minim[illegible] of the fiber, values of Young's m[illegible]ulus reported herein are proba[illegible] slightly in excess of the true mod[illegible] of the fibers. Proportional limit str[illegible]

nd work to failure also were com- ited using the cross-sectional area at e point of failure as a basis for stress l volume computations, respec- ely.

Average values and the ranges of mechanical properties of the spe- s tested are shown in Table 1. Each ry for earlywood and latewood is average of ten values with the ception of those for proportional it stresses. Of the ten earlywood rs of Douglas-fir tested none ex- ited a proportional limit, and sev- l early- and latewood fibers of the aining species did not exhibit a t of proportionality. Consequently, ne of the proportional limit entries based on less than ten but no fewer than six values.

Each group of three stress-strain diagrams in Figs. 3–22 portrays average properties and also the approximate range of fiber properties of the particular group represented. The short horizontal line drawn across each curve designates the proportional limit. The average relationship of stress to strain is pictured by the center diagram of each figure. The slope of the lower portion, shown in continuous line form to the proportional limit, is the average Young's modulus. The upper broken line portion of the average diagram, was fitted by eye as representative of the stress-strain relationship between the proportional limit and failure stress. It should be noted that this region of the diagram is only an approximation. Its precise form must await the development of viscoelastic theory for wood fibers.

The remaining two diagrams of each figure were selected as representative of the range of mechanical properties of the particular group. In general, the diagram of lower slope depicts the fiber possessing one of the lowest values of Young's modulus and tensile strength, whereas the uppermost diagram represents the fiber having one of the higher values of the two mechanical properties. High or low values of work to failure and

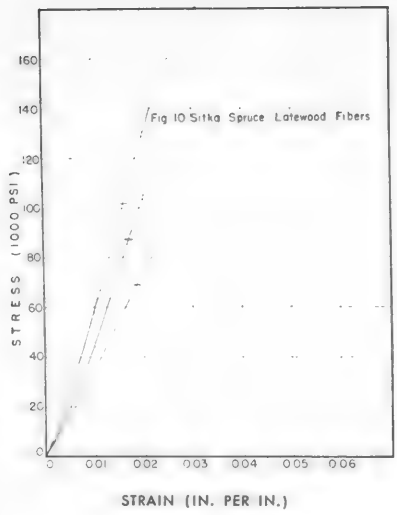


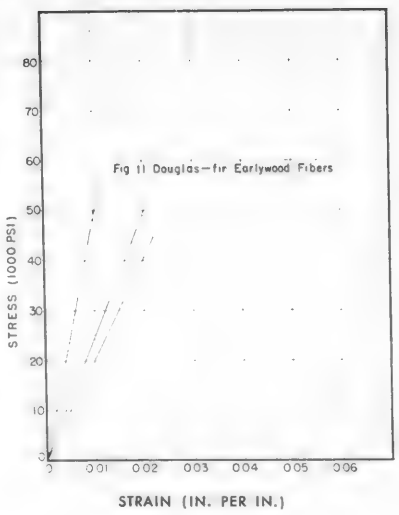
deformation at failure were not consistently associated with either high or low values of either the modulus or tensile strength. However, those fibers which sustained a large increment of deformation usually absorbed a great deal of energy before failure. Since maximum or minimum values of the properties were rarely observed in one fiber only, data taken from either the upper or lower diagram do not necessarily correspond to the maximum and minimum of each set of range values shown in Table 1. It is interesting to note from the three diagrams in Fig. 8 for latewood fibers of western redcedar that increasing tensile strength is associated with a decreasing Young's modulus. Fibers of no other species exhibited this unusual behavior.

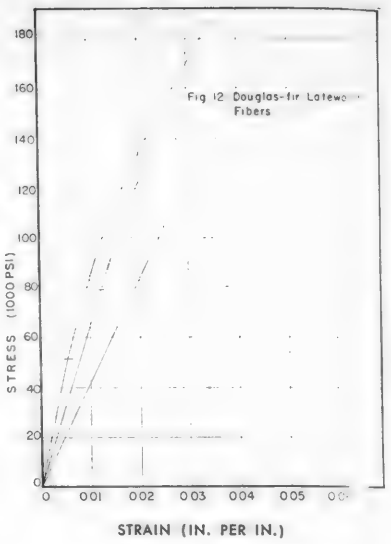
The existence of a limit of proportionality in virtually all the stress-strain diagrams is ample evidence that the wood fiber is a viscoelastic medium. Hence, the proportional limits computed cannot be accepted as fixed values. Rather, they illustrate only the point in stress in this particular experiment at which viscous response overshadowed elastic response. Investigations of other natural and also synthetic fibers as well as plastics, all of which are high polymers, and as such resemble wood fiber, has demonstrated that the experimental manifestation of elastic and viscous behavior and the degree to which each is present is closely dependent on experimental error, time or rate of deformation, temperature, and relative humidity in the case of moisture-adsorbing polymers. Consequently, it is very likely that future research on wood fiber machines will demonstrate that a proportional limit can exist at virtually any level of stress or be nonexistent depending on the test conditions. Its presence at a particular stress level in these results comes about by virtue of the experimental conditions

Table 1.—STRESS-STRAIN PROPERTIES OF WOOD FIBERS

	Cross-sectional Area, sq. in. x 10-6	Tensile Strength, lb. per sq. in.	Young's Modulus, lb. per sq. in. x 10-6	Strain at Failure, in. per in.	Work to Failure, in lb. per in.	Proportional Limit Stress, lb. per sq. in.
Redwood Earlywood Fibers						
Average	0.35	69,000	2.50	.034	1200	47,000
Range	0.24-0.53	53,000- 96,000	2.01-3.39	.021-.065	600-1800	33,000- 62,000
Redwood Latewood Fibers						
Average	0.57	130,000	4.25	.030	2000	71,000
Range	0.41-0.74	98,000-171,000	2.78-6.10	.024-.034	1400-2700	48,000-103,000
Sitka Spruce Earlywood Fibers						
Average	0.40	117,000	4.26	.026	1500	82,000
Range	0.24-0.56	77,000-175,000	3.27-6.16	.018-.035	600-2200	53,000-133,000
Sitka Spruce Latewood Fibers						
Average	0.52	129,000	5.13	.025	1600	88,000
Range	0.33-0.76	83,000-165,000	3.42-7.45	.020-.032	900-2200	54,000-118,000
White Spruce Earlywood Fibers						
Average	0.29	77,000	3.77	.025	1000	44,000
Range	0.18-0.51	66,000- 90,000	2.12-4.96	.014-.040	700-1400	32,000- 65,000
White Spruce Latewood Fibers						
Average	0.44	85,000	5.34	.019	800	59,000
Range	0.21-0.71	77,000- 98,000	3.02-8.72	.009-.028	300-1100	42,000- 76,000
Slash Pine Earlywood Fibers						
Average	0.84	47,000	1.66	.034	800	32,000
Range	0.44-1.82	35,000- 78,000	0.78-2.67	.017-.057	500-1200	10,000- 48,000
Slash Pine Latewood Fibers						
Average	1.06	92,000	3.13	.034	1600	37,000
Range	0.52-1.46	61,000-196,000	1.47-5.38	.022-.046	700-3800	24,000- 65,000
Douglas-fir Earlywood Fibers						
Average	0.53	51,000	2.64	.021	600	-----
Range	0.37-0.75	42,000- 58,000	1.68-4.76	.011-.027	300- 800	-----
Doulgas-fir Latewood Fibers						
Average	0.80	142,000	6.35	.024	1700	78,000
Range	0.61-1.28	114,000-185,000	4.12-9.57	.012-.035	600-3200	52,000-104,000
White Fir Earlywood Fibers						
Average	0.47	73,000	2.97	.025	900	52,000
Range	0.26-0.76	45,000- 87,000	2.26-3.64	.014-.035	500-1300	21,000- 75,000
White Fir Latewood Fibers						
Average	0.54	104,000	4.09	.024	1400	71,000
Range	0.38-0.70	76,000-168,000	2.98-5.75	.019-.032	900-2500	44,000-128,000
Western Redcedar Earlywood Fibers						
Average	0.56	49,000	1.85	.030	700	43,000
Range	0.43-0.89	27,000- 69,000	1.11-3.31	.018-.044	500-1400	25,000- 57,000
Western Redcedar Latewood Fibers						
Average	0.51	68,000	3.46	.024	900	50,000
Range	0.32-0.87	56,000- 86,000	2.07-6.67	.008-.034	200-2100	38,000- 78,000
Cypress Earlywood Fibers						
Average	0.44	81,000	2.59	.034	1400	43,000
Range	0.22-0.61	66,000-110,000	1.64-3.78	.026-.050	1000-2000	33,000- 59,000
Cypress Latewood Fibers						
Average	0.69	148,000	5.33	.032	2400	74,000
Range	0.36-1.05	119,000-187,000	2.85-8.64	.025-.043	1900-2700	41,000-103,000
Western White Pine Earlywood Fibers						
Average	0.65	60,000	2.64	.024	700	45,000
Range	0.38-1.00	42,000- 73,000	1.99-4.37	.014-.037	400-1300	32,000- 58,000
Western White Pine Latewood Fibers						
Average	0.87	66,000	2.37	.027	900	38,000
Range	0.47-1.68	50,000- 76,000	1.02-4.14	.016-.035	400-1100	17,000- 60,000
Western Hemlock Earlywood Fibers						
Average	0.36	84,000	3.12	.026	1100	70,000
Range	0.18-0.53	61,000-106,000	1.02-4.83	.015-.033	600-1500	43,000- 87,000
Western Hemlock Latewood Fibers						
Average	0.64	131,000	4.45	.027	1800	64,000
Range	0.33-1.04	94,000-177,000	2.60-6.21	.010-.038	700-3400	45,000- 99,000





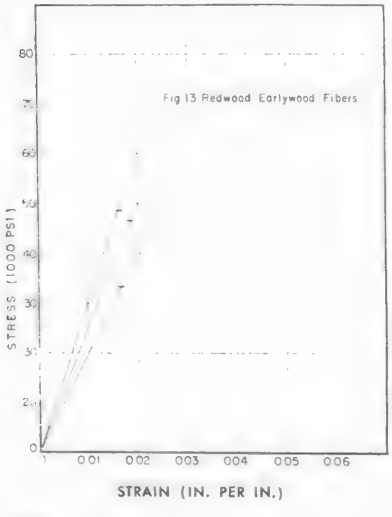


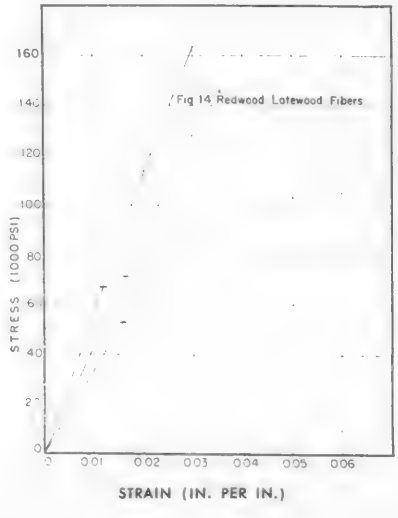
and the accuracy and magnification of the recording instruments.

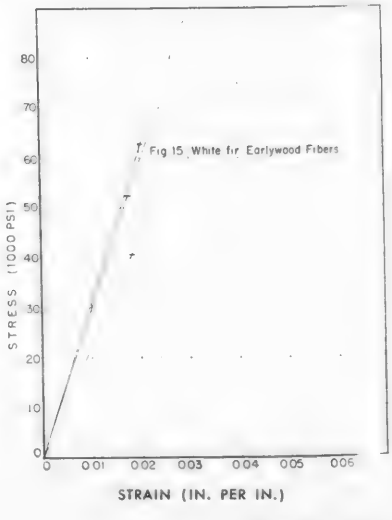
The ten species examined can be divided into two groups, one comprised of four and the other of six species. This arbitrary division is based on the occurrence of similar or dissimilar stress-strain behavior of early- and latewood fibers within a single species. As shown by Figs. 3–8 and Table 1, in general western white pine, white spruce and western redcedar produce early- and latewood fibers of similar mechanical properties. Values of tensile strength did not exceed 100,000 lb. per square inch. and values of Young's modulus ranged from approximately 2.0–5.0 x 10^6 pound per square inch. for all fibers of the three species. Strain at failure ranged from 2 to 3 percent for the three species and, stress at proportional limit ranged from 40,000 to 60,000 pounds per square inch. Of the three species, latewood fibers of white spruce and western white pine revealed the least dispersion of mechanical properties (Table 1). The proportional limit stresses of the three averaged approximately 70 percent of ultimate strength. It is interesting to note from the data of Table 1 that for earlywood fibers of western redcedar the non-linear portion was restricted to the upper 12 percent of the stress-strain diagram. Apparently, the flow mechanisms of this type of fiber are not activated appreciably until high levels of stress are attained. As can be noted from Figs. 3–8, several representative fibers manifest a linear stress-strain relation to failure.

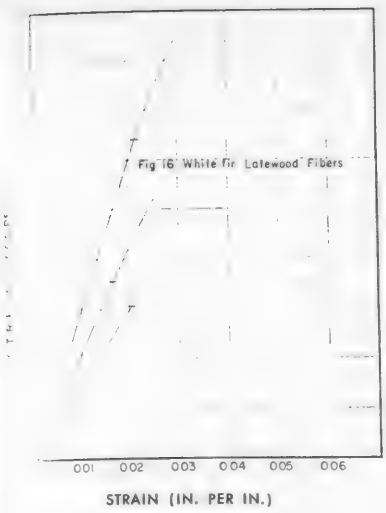
Fibers of Sitka spruce exhibited the most unusual character of the ten species examined. Although both early- and latewood fibers showed similar ranges of tensile strength and Young's modulus, the stress-strain diagrams were sigmoid, (Figs. 9 and 10) rather than linear in the lower region addended by a curvilinear region above the proportional limit. The reverse curvilinearity in the lower region of the diagrams depicts a fiber that is increasing in stiffness as load is applied. It is likely that at a relative humidity of 50 percent sufficient moisture is present in the amorphous regions of the cell wall to permit the cellulose molecules to shift into a position more nearly aligned with the direction of principal stress, i.e., parallel to the longitudinal axis of the fiber. Consequently, increasing fiber stiffness with increasing stress comes about partially as a result of a greater contribution of elastic deformation within the cellulose molecule to the overall amount of deformation. The straightening of cellulose chains may result also in some increase of crystalline volume. This phenomenon may occur both in localized regions where the chain molecules become aligned and at the fringes of existing crystalline areas. An increase in the degree of crystallinity also will tend to increase Young's modulus of the fibers.

Unreported data collected by the writer indicate that curvilinearity in the lower region of the stress-strain









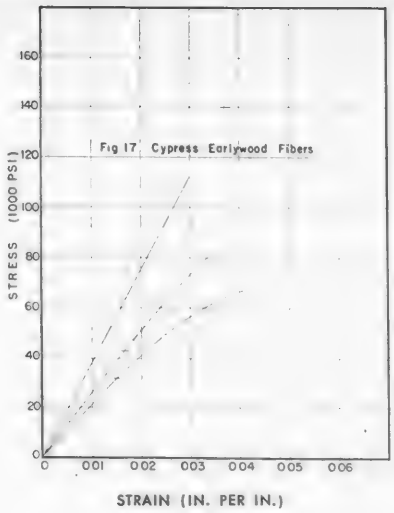


diagram is more prominent and persists at higher stresses in wood fibers when deformed in an atmosphere of relative humidity in excess of 50 percent[3]. This is to be expected considering the increased mobility of cellulose in the amorphous regions when in the presence of increasing amounts of moisture. Apparently, the cellulose matrix exists in an inherently more mobile state in Sitka spruce. This would seem to account for its stress-activated realignment at a relative humidity which is too low for a similar phenomenon to occur in the remaining fibers. The entire average stress-strain diagrams of Figs. 9 and 10 for Sitka spruce were reproduced as broken lines to emphasize their approximate nature. Values of Young's modulus were computed from the slope of a line connecting the origin with the proportional limit of each diagram.

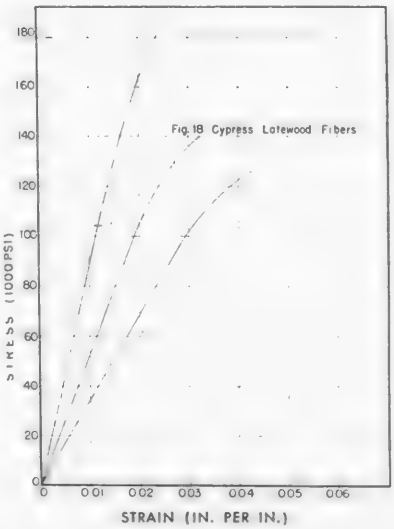
Each of the remaining six species tested, Douglas-fir, redwood, white fir, cypress, western hemlock, and slash pine were characterized by marked differences in the mechanical behavior of the earlywood as contrasted to latewood fibers. As shown by the data in Table 1 and Figs. 11, 13, 15, 17, 19, and 21, for the most part the early wood fibers of these six species were confined to the range of 30,000 to 120,000 pounds per square inch. tensile strength. Slash pine and western redcedar fibers fixed the lower end of this range and, cypress and western hemlock earlywood fibers set the upper limit. With the exception of Douglas-fir the majority of earlywood fibers of these species exhibited a proportional limit. This peculiarity on the part of Douglas-fir stands as tentative evidence of a cellulose more highly cross-linked and less subject to viscous flow than in the remaining fibers. Future rheologic research over a range of temperatures and relative humidities should aim at the elucidation of this behavior.

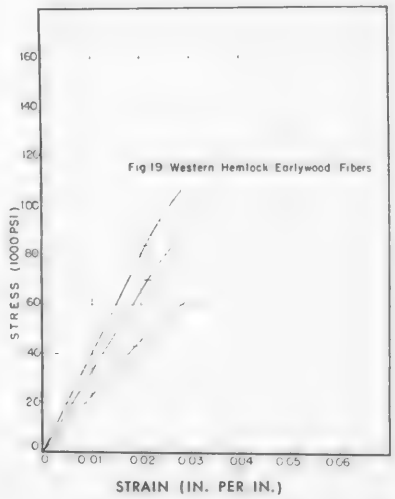
For the six species mentioned above, the stress at proportional limit averaged approximately 70 percent of ultimate strength. It ranged from a low of 53 percent for cypress to a high of 83 percent for western hemlock. It is interesting to note that a representative earlywood fiber of cypress exhibited a linear stress-strain relation to failure. As stated previously, little stock should be placed in proportional limit stresses as their values are dependent on the conditions of testing. They should be interpreted as a reflection of viscous flow in the fiber, most likely at the molecular level, and as such can serve as tentative indicators of differences in the molecular architecture of the different fibers.

The latewood fibers of the six species also demonstrated similar mechanical properties. Stress-strain diagrams of these fibers are pictured in Figs. 12, 14, 16, 18, 20, and 22. Average and range values of mechanical properties are shown in Table 1. Inspection of Fig. 12 shows that a representative latewood fiber of Douglas-fir failed to exhibit a proportional limit. Of the ten latewood fibers tested of this species, only six fibers possessed a proportional limit. Proportional limit stress averaged approximately 53 percent of ultimate strength for the latewood fibers of these six species. It ranged from a low of 40 percent for slash pine to a high of 68 percent for white fir.

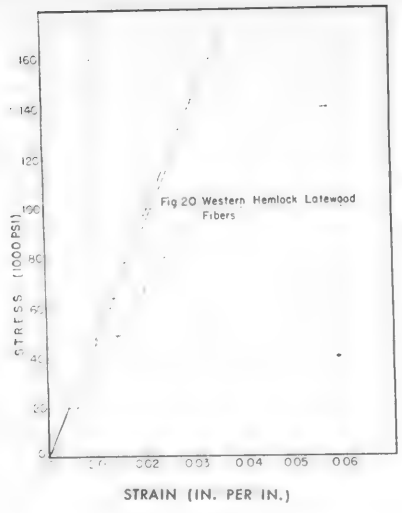
Latewood fibers of western hemlock, Douglas-fir, Cypress, and redwood, had minimum tensile strengths of approximately 100,000 pounds per square inch. and ranged upward to maximum values approaching 200,000 pounds per square inch. Further comparison of the earlywood with latewood fiber stress-strain diagrams of these six species as well as inspection of the data in Table 1 shows clearly that the latewood fibers surpass the earlywood fibers in stiffness, work to failure, and proportional limit stress as well as tensile strength. It is emphasized that these data are based on the material cross section of the fiber exclusive of the lumen. Hence, differences in all mechanical properties must be attributed primarily to fundamental differences in fiber molecular structure. It is recognized also that fiber geometry, its previous history, and the method of clamping will introduce some slight differences between the properties of the various fibers.

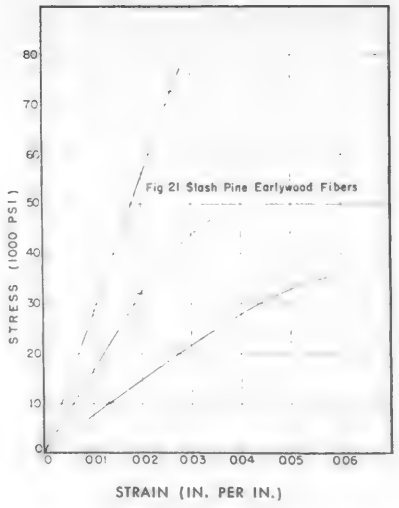
Considering all fibers, in general the earlywood fibers sustained a greater amount of total strain at failure than the latewood fibers. However, this was not without exception as shown by Table 1, where earlywood fibers of western white pine, western hemlock, and Douglas-fir sustained less total strain than latewood fibers

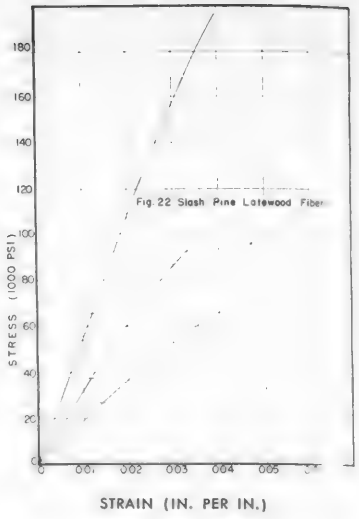




[3] See footnote 2, page 3.







of the same species. The degree to which fibers can be deformed before failure also can serve as a valuable indicator of differences in their molecular constitution. Future research in which temperature and relative humidity effects can be observed should prove invaluable for further clarification of the phenomenon of failure.

It is interesting to consider what possible mechanisms can account for the tremendous difference in tensile strength between the individual fiber and sawn wood. Much, but not all of the difference, can be attributed to relative density. In addition it is probable that stress concentrations in sawn wood, at the macro-level due to external shape and at the micro-level due to ray tissue, early- latewood boundaries, and other anatomical features significantly lower the stress absorbing capacity of wood. A combination of these two factors may be sufficient to explain observed differences. In turn stress concentrations exist within the individual fiber during straining due to differences in wall structures and the relative degree of organization of crystalline as compared to amorphous regions. Stress concentrations of this sort can serve to reduce the tensile strength of the fiber six to ten fold below that of the cellulose chain molecule.

Summary and Conclusions

Using an electrical-mechanical system for measuring force and deformation, it is possible to measure accurately the load-deformation properties of single fibers of wood. The data accumulated from tests of fibers of ten coniferous trees demonstrate not only vast differences between fibers of different species but also frequently between early and latewood fibers of a single species.

In this research, testing was limited to measurement of the relationship between load and deformation. For the most part, stress-strain curves were linear to stresses in the range of 50 to 70 percent of maximum. At this point proportionality between force and deformation ceased and deformation increased at an increasing rate. Both early- and latewood fibers of Sitka spruce provided a notable exception to this general behavior. Their stress-strain functions were sigmoidal. In the lower region of the diagrams deformation decreased at a decreasing rate and, later, beyond the proportional limit, increased at an increasing rate. The inflection point was considered as the conventional proportional limit. It is suggested that this unusual behavior is a reflection of stress-activated structural changes in the cellulose matrix. Future research may demonstrate that these characteristics are influenced significantly by the relative humidity and temperature conditions surrounding the fiber during testing.

It is emphasized that the proportional limit stress is not a fixed value but is a function of the test conditions, i.e., rate of deformation, relative humidity, temperature, and to some extent fiber geometry and other environmentl conditions of testing. Its existence should be interpreted as a manifestation of molecular flow occurring in the fiber in addition to elastic deformation. Future research of this phenomenon should be directed toward the formulation of a viscoelastic theory which will describe the mechanical response of the fiber irrespective of the time-rate of load application.

Literature Cited

1. Alfrey, T. 1948. *Mechanical behavior of high polymers.* Interscience Publishers, Inc., N. Y.
2. Eyring, H. and G. Halsey. 1946. Mechanical properties of textiles. *Ex. Res. J.* 16: 13–25. (See also 15: 95–311 and 451–9. 1945. 16: 53–60. 124–129, 201–10, 329–34, 335–37, 37[illegible]81, 382–89, and 635–42. 1946.)
3. Greenhill, W. L. 1942. The damping capacity of timber. *Jour. Coun. Sci. and Ind. Res., Div. of For. Prod.* 15(2): 146–163. Australia.
4. Jayne, B. A. 1959. Mechanical properties of wood fiber. *Tech. Assoc. Pulp and Paper Ind.* 42(6): 461–7.
5. Leaderman, H. 1943. *Elastic and creep properties of filamentous materials and other high polymers.* The Textile Foundation. Washington, D. C.
6. Leaderman, H. 1958. *Rheology.* Vol. 2. edited by F. R. Eirich. Chapter 1. Viscoelastic phenomena in amorphous high polymer systems. Academic Press, Inc. New York.
7. Meredith, R. 1956. *The mechanical properties of textile fibers.* Interscience Publishers, Inc. New York.
8. Narayanamurti, D. and D. N. Prasad. 1949. The damping capacity of some indian timbers. *Jour. Aeronautical Soc. of India.* 1(3): 30–37.
9. Pentoney, R. E. 1956. *On the low stress rheologic behavior of wood.* PhD. Thesis. College of Forestry, State University of New York.
10. Rohloff, E. 1940. Ueber die innere Reibung von Geigenholz. *Z. Phys.* 115: 64–66.
11. Rühlemann, F. 1932. *Thesis.* Tech. Hochschule, Dresden. 63 p.
12. Spearin, W. F. and I. H. Isenberg. 1947. The maceration of woody tissue with acetic acid and sodium chlorite. *Science* 105: 214.
13. Van den Akker, J. A., A. L. Lathrop, M. H. Volker, and L. R. Dearth. The Importance of fiber strength to burst strength. *Tech. Assoc. Pulp and Paper Ind.* 41(8): 416–25.
14. Wardrop, A. B. 1951. Cell wall organization and the properties of the xylem. I. Cell wall organization and the variation of breaking load in tension of the xylem in conifer stems. *Aust. J. Sci. Res.* B 4(4): 391–41[illegible]
15. Wise, L. E., M. Murphy, and A. A. D'Addieco. 1946. Chlorite holocellulose, its fractionation and bearing on summative wood analyses and on studies on the hemicelluloses. *Paper Trade Jour.* 122: 35–43.

Diffusion Through Air-Filled Capillaries of Softwoods—Part II: Water Vapor[1]

HAROLD TARKOW AND ALFRED J. STAMM

Forest Products Laboratory,[2] Forest Service, U. S. Department of Agriculture

THE RESULTS OF AN EXPERIMENTAL study of the diffusion of carbon dioxide through dry Sitka spruce was covered in Part I of this paper.[3]

The rate of diffusion in the transverse direction is very appreciably smaller than the value calculated from the geometry of the capillaries and the normal bulk value for the diffusion coefficient of carbon dioxide in air.

According to the Internationl Critical Tables, the normal bulk diffusion coefficient for moisture in air at 30° C. is 0.27 square centimeter per second. The corresponding value for carbon dioxide in air is 0.17 square centimeter per second. In both cases, the concentration gradient is expressed in terms of grams of water or carbon dioxide diffusing per cubic centimeter of air. Thus for the same concentration gradient, water vapor diffuses 1.6 times as fast as carbon dioxide. The ratio calculated from Graham's Law (which states that the diffusion coefficients are inversely proportional to the square root of the molecular weights) is 1.56. The experimental values for the diffusion coefficient of carbon dioxide in the transverse and the fiber directions reported in Part I can therefore be converted to the corresponding D_{H_2O} vapor value by multiplying the values by 1.6. The value for the transverse diffusion of water vapor in dry Sitka spruce is therefore $7.5 \times 10^{-5} \times 1.6$ or 1.2×10^{-4} square centimeters per second. The value in the fiber direction is 8.0×10^{-2} square centimeters per second. These values represent the diffusion coefficient of water vapor in the transverse and longitudinal directions under nonswelling conditions; e.g., with no contribution by bound water movement. It is assumed that the movement of water vapor in the air-filled spaces of wood is analogous to the movement of carbon dioxide through wood. It is also assumed that the mean free path of CO_2 at atmospheric pressure is the same as that of water vapor at a total pressure of one atmosphere.

The transverse diffusion coefficient of moisture through wood at low moisture content values is predictable from the diffusion constant of carbon dioxide. At low moisture content values, therefore, moisture movement is essentially water-vapor movement through the air-filled capillaries.

There are a number of indications that the rate of bound water movement through cellulosic substance decreases with decreasing moisture content. The last traces of moisture in wood are very difficult to remove. Hermans[4] found that if rayon, dried over phosphorus pentoxide, is exposed to different relative humidities the time required to attain equilibrium is increased by a factor of 100 if the relative humidity falls off from 85 to 18 percent. Such an effect of concentration seems to be typical for the diffusion of vapors through polymeric materials. Thus, Long[5] reports that the rate of diffusion of acetone through cellulose nitrate decreases rapidly as the vapor pressure of acetone decreases.

The overall diffusion constant of moisture through wood has contributions from both vapor movement and bound water movement. There is no reason to expect the former contribution to be dependent on the level of moisture content. With decreasing moisture content, therefore, an increasing percentage of the over-all D_{H_2O} is due to vapor diffusion; e.g., movement in air-filled capillaries. In fact, at low enough moisture contents the diffusion may be essentially a vapor diffusion. If this is so, then the D_{H_2O} under these conditions should be related to the diffusion constant of CO_2 in wood; e.g., D_{CO_2}. Experiments were made to verify this.

Experimental Procedure

The apparatus used was essentially that described in Part I. Air, conditioned at a definite relative humidity by bubbling through aqueous sulfuric acid, was passed through one compartment. Dry air was passed through the other compartment where it picked up the moisture that had diffused through the membrane, thence it was passed through a dehydrite weighing tube, and vented to the atmosphere through a second dehydrite tube in series with an ethylphthalate bubbler. Preliminary measurements with dry air passing through both compartments of the cell showed that a very small but constant amount of moisture (0.5 milligram per hour) was being picked up in the weighing tube. The amount was too small to seriously affect the assumption that the relative humidity on the dry side was

The authors: Harold Tarkow, a research chemist, holds a Ph.D. from the University of Wisconsin. He has been with the USFPL since 1935, concentrating primarily on dimensional stabilization and adhesion. Alfred J. Stamm, formerly a subject matter specialist at the Laboratory, holds a Ph.D. from Wisconsin. He is now on the faculty of North Carolina State College.

[1] A contributed paper received August 20, 1959.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Tarkow, Harold and Stamm, A. J. 1960. Diffusion through the air-filled cappillaries of softwoods. Part I: carbon dioxide. For. Prod. Jour. X (5) 247–250.

[4] Hermans, P. H. 1946. Contribution to the physics of cellulose fibers. Elsevier Pub. Co.

[5] Long, F. A. 1953. Diffusion of acetone into cellulose nitrate films. Jour. Pol. Science No. 10, p. 241.

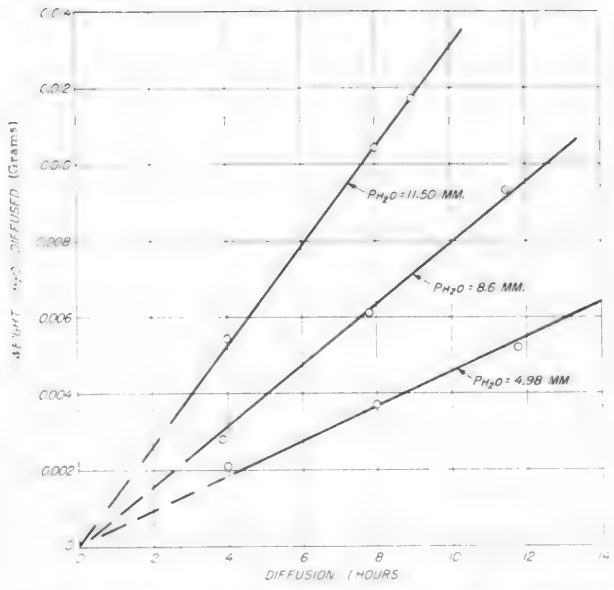


Fig. 1.—Rate of diffusion of water vapor through 1/32-inch radially sliced Sitka spruce veneer of low moisture content at different vapor pressures.

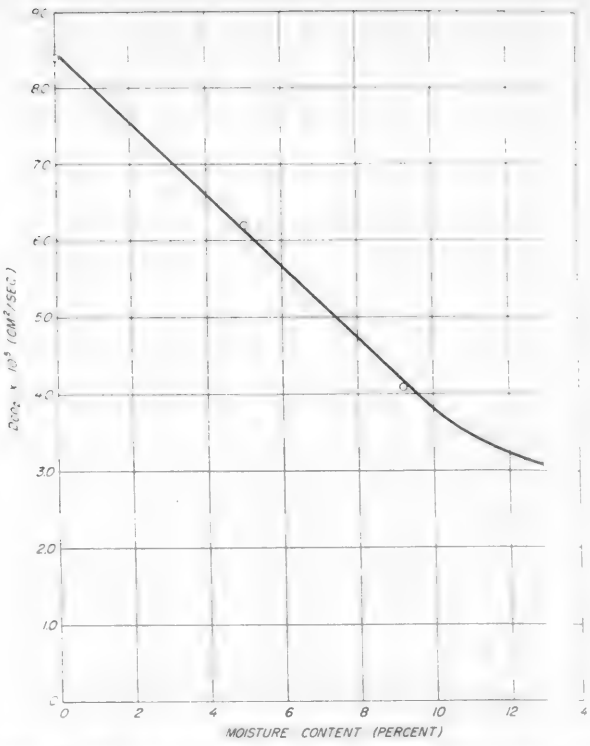


Fig. 2.—Effect of moisture content on the diffusion coefficient of carbon dioxide (D_{CO_2}) through 1/32-inch Sitka spruce veneer.

0 percent. This moisture undoubtedly represented the more difficultly removable water in the "dry" wood. During an experiment, the actual amount of water diffusing across the membrane as a result of a gradient was obtained by subtracting this small constant gain.

D_{CO_2} was first determined for the veneer (as described in Part I). The calculated D_{H_2O} vapor value was obtained by multiplying by 1.6. D_{H_2O} was then determined experimentally. The diffusion plots are shown in Figure 1. The data are not as accurate as those for the carbon dioxide diffusion because partial pressure gradients with water vapor are much smaller. The transverse passage of water vapor through 1/32-inch Sitka spruce veneer is given below. In these tests, one face of the veneer was maintained at 0 percent relative humidity, and the other face was maintained at the relative humidity indicated.

The value at 0 percent relative humidity is the D_{CO_2} value multiplied by 1.6, With decreasing relative humidity, D_{H_2O} appears to decrease slowly to approximately the value calculated from D_{CO_2}. This value is reached at between 20 to 30 percent relative humidity. In other words, below 20 to 30 percent relative humidity, the transverse diffusion of moisture through wood is predictable from the value of D_{CO_2}. The diffusion here must occur almost entirely as water vapor through the air-filled capillaries. It follows that the transverse movement of moisture vapor through wood at these low relative humidities is determined essentially by the rate of movement through the pores of the pit membrane as was shown in Part I to be the case for the diffusion of carbon dioxide. Such water vapor diffusion (in the air-filled spaces) must, then, also be appreciably smaller than the calculated value, assuming a normal bulk diffusion constant, because of the marked influence of the walls of the pit membrane pores. At relative humidities above 30 percent, D_{H_2O} increases significantly. This is due to an increasing contribution to the overall diffusion by bound water diffusion, as was shown by Stamm in measurements of bound water diffusion.[6]

Relative humidity (Percent)	D_{H_2O} (10^{-4} cm.^{2}/sec.)
Specimen A	
36.1	1.3 ±0.05
27.1	1.1 ±0.10
15.7	1.0 ±0.15
0.0	1.1 (calculated)
Specimen B	
49.1	2.4 ±0.10
37.4	2.1 ±0.10
28.2	1.4 ±0.10
16.0	1.7 ±0.10
0.0	1.3 (calculated)

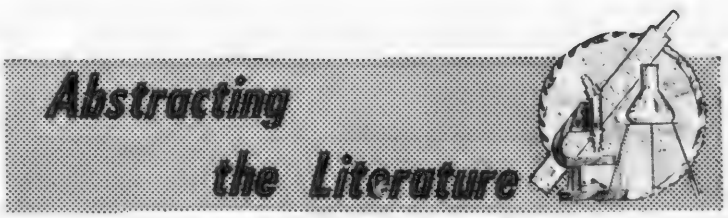
[6] Stamm, A. J. 1959. Bound-water diffusion into wood in the fiber direction. For. Prod. Jour. IX (1):27-32.

A few measurements were made of the diffusion coefficient of carbon dioxide through transverse sections of Sitka spruce at four different moisture contents obtained by preconditioning the specimens to different relative humidities. The data are given in Figure 2. They show that the diffusion coefficients decrease with an increase in moisture content.

Discussion and Conclusion

The most important finding of this part of the study is that the transverse diffusion coefficient of moisture through wood at low moisture contents, is predictable from the diffusion constant of carbon dioxide. This means that at low moisture contents, the movement of moisture is essentially as water vapor movement through the air-filled capillaries of the wood. With increasing moisture content, bound water diffusion becomes increasingly important and the overall diffusion increases.

The interpretation of the second finding, that D_{CO_2} decreases with increasing moisture content is not clear and must wait for more data. Certainly one of the complications is that of the increasing association of carbon dioxide with water molecules with increasing moisture content.



Christensen, G. N., and Kelsey, Kathleen E. The sorption of water vapour by the constituents of wood. III. The swelling of lignin. Australian J. Appl. Sci. 10, no. 3: 284–93 (Sept., 1959); *cf.* abstr. no. 2,158.

Measurements of swelling during the sorption of WV have been made on samples of Klason and methanol lignin from *Eucalyptus regnans* F. Muell. by compressing the lignin into small blocks and exposing these blocks to successive changes in R.H. By making some simple assumptions, it was possible to distinguish between the water which entered the lignin structure to cause swelling and that deposited in existing void spaces without causing swelling. It was found that between rel. vapor pressures of approx. 0.2 and 0.9, more than half the water being adsorbed entered the lignin structure, this fraction reaching a max. of 0.78–0.92 for the Klason lignin and 0.62–0.67 for the methanol lignin. At rel. vapor pressures below 0.2, most of the water adsorbed did not contribute to swelling, presumably being held by surface adsorption. At rel. vapor pressures above 0.9, the proportion of adsorbed water contributing to swelling decreased rapidly, due to the increasing preponderance of capillary condensation in the void spaces. The results thus demonstrate that during sorption of WV, lignin behaves predominantly as a swelling gel, rather than as a rigid porous adsorbent. 9 ref. [A.B.I.P.C. 30:5]

Gardner, J. A. F., Barton, G. M. and MacLean, H. (Forest Prods. Labs. of Can., Vancouver Lab.). The polyoxyphenols of western red cedar. (*Thuja plicata* Donn.) I. Isolation and preliminary characterization of plicatic acid. Can. J. Chem. 37, no. 10: 1703–9 (Oct. 1959).

An amorphous, opt. active, heat- and light-sensitive polyoxyphenolic acid has been isolated from the mixt. of polyoxyphenols present in the aq. ext. of western red cedar. Analyses of cryst. derivs. are consistent with a mol. formula of $C_{20}H_{22}O_{10}$. Color tests, spectra, methylation, and alk. nitrobenzene oxidin. indicate it to be a propylphenol dimer, a lingin acid, in which one aromatic ring is 3-methoxy-4-hydroxyphenyl and the other is 3,4-dihydroxy-5-methoxyphenol. Acetylation results and lactone formation require the presence of three alc. hydroxyls, one of which is in γ-position to the carboxyl. 13 ref. [A.B.I.P.C. 30:5]

Kelsey, Kathleen E., and Christensen, G. N. The sorption of water vapour by the constitutents of wood. II.

The equipment for the purpose of introducing oxygen into the water presented no serious installation or operational difficulties. The amt. of oxygen absorbed by the water in passing through the turbine seems principally dependent on the dissolved-oxygen satn. level of the water, and seems principally dependent on the dissolvupon amt. of air admitted. By introducing air into the housing of the turbine, an increase of 0.16 p.p.m. dissolved oxygen, or a gain of 525 to 9471 lb. of oxygen/day/100 cu. ft./sec., was obtained depending on test conditions. The max. oxygen-absorption effciency amounted to 37.3%. Introducing air into theturbine results in a loss in power consumption. The waters passing through a turbine when air is not being admitted may lose a portion of the dissolved oxygen. A decrease in B.O.D. may be obtained by turbine venting. Stream aeration by means of turbine venting is superior to aeration by compressor and air diffusion through tubes and plates. 5 ref. [A.B.I.P.C. 30:5]

Lengyel, Pál. Systematic investigations of domestic [Hungarian] poplars. Budapest, Papíripari Kutatóintézet [Research Inst. of the Hung. Paper Ind.] Rept. No. ETO: 676.16.036.1, 1958. 50 p. [Hung.; Russ. and Ger. sum.]

The phys., chem., and pulping characs. of the 5 species of poplars growing in Hungary were evald. *Populus canadensis* possessed the greatest lignin content (23.1%) and quaking aspen (*P. tremula*) the lowest (18.4%). Differences in carbohydrate contents were rel. smaller. Alc.-benzene extvs. were most abundant in white poplar (*P. alla*) and comprised mostly heartwood resins. The inorg. (ash) content of the trees examd. depended largely on the climatic and soil conditions. Poplarwood is suitable for the mfr. of groundwood. Although poplar groundwood does not equal the breaking length of spruce groundwood, it is superior in whiteness and yield. Black poplar (*P. nigra*) groundwood showed the highest strength props. *P. canadensis* groundwood the greatest whiteness, and *P. alba* groundwood the highest prodn. yield but also the greatest pitch troubles (caused by its high resin content). Best results in the mfr. of chem. pulps were obtained with Can. poplar, although pulps from "giant poplar" (*P. robusta* hybrid poplar) showed good strength props. The mfr. of mechano-chem. pulp from aspen is based on the low lignin content of this sp. 14 ref. [A.B.I.P.C. 30:6]

Meier, Hans. Distribution of hemicellulose components in pinewood fibers. Svensk Papperstidn. 62, no. 19: 687–91 (Oct. 15, 1959). [Swed.; Ger. and Engl. sum.]

Pinewood tracheids in different stages of devt. were isolated with a micromanipulator. After hydrolysis of the fractions, the sugars were detd. quant. by paper chromat. The younger fibers, which are composed only of the middle lamella (M) and the primary wall (P), were found to consist mainly of pectic substances (pectic acid, galactan, and araban). In older fibers, in which a transition layer (outer layer of the secondary wall, S_1) had been deposited, the peptic substances were found to diminish, whereas cellulose, glucomannan, and glucurono-araboxylan (*I*) *increased*. In still older fibers (M + P + S_1 + S_2), the glucomannan content showed a further increase, whereas *I* diminished. In fully devd. fibers (containing S_1 + S_2 + S_3 in addn. to M + P), the *I* increased strongly and thus seemed to be localized mainly in the tertiary wall (inner layer of the secondary wall, S_3), whereas the glucomannan must be concd. mainly in the central layer of the secondary wall (S_2). This distribution of the polysaccharides through the fiber wall was confirmed by anal. of springwood and summerwood. The springwood, in which the S_2 layer is thinner than in the summerwood, always contained less glucomannan and more *I* than did the summerwood. 6 ref. [A.B.I.P.C. 30:6]

Nyrén, V[era] and Back, E[nrst]. The resin in parenchymatous cells and resin canals of conifers. V. The ray volume in *Pinus silvestris* stemwood and its distribution between tracheidal and parenchymatous ray cells. Svensk Papperstidn. 62, no. 19: 681–6 (Oct. 15, 1959). [ngl.; Swed. and Ger. sum.] *cf.* A.B.I.P.C. 30: 656.

Representative tangenitial sections of pine stemwood were taken by stratified sampling of 7 trees growing at 60° northern latitude and evald. for their ray area. A mean stemwood ray vol. of 3.9% (with a 90% confidence limit of 0.4%) was obtained. Less than 10% of this vol. was made up of multiseriate rays with resin canal. Radial resin canals accounted for 0.05% of the stemwood vol. (with a 90% confidence limit of 0.02%). Of the total ray vol., 45% was tracheidal and 53% parenchymatous, the 2% deficit being attributable to radial resin canals and radial intercellular channels bordering on the ray parenchyma cells. On the av., 29 uniseriate rays/sq. mm. of tangential sections were found; their height distribution showed a max. at a height of 4–5 cell rows. The mean proportion of tracheidal ray rows was 54% for all rays and slightly higher (57%) for uniseriate rays. The over-all proportion of tracheidal and parenchymatous cells in rays of different height is given, as well as the frequency of the various possible combinations of tracheidal and parenchymatous cell rows in rays 2–9 cell rows high. The wt. proportion of ray cells plus vert. and other types of parenchyma cells in *P. silvestris* kraft pulps was estd. at

8% by a pulp-fractionation method. The wt. proportion of tracheidal to parenchymatous ray cells was estd. at 7:3, based on cell and cell-wall dimensions obtained in previous investigations. 12 ref. [A.B.I.P.C. 30:6]

Roff, J. W., and Whittaker, E. I. (Forest Prods. Labs. of Can.) Toxicity tests of a new tropolone, β-thujapalicinol (7-hydroxy-4-isopropyltropolone) occurring in western red cedar. Can. J. Botany 37, no. 5: 1132–4 (Sept., 1959).

In biol. tests against 5 wood-destroying fungi, the recently isolated β-thujaplicinol (*I*) was found to resemble the thujaplicins (*II*) in controlling brown rots but to be less effective against white rots. Since *I* is only one tenth as abundant in red cedar heartwood as are *II*, it appears to contribute only slightly to the decay resistance of western red cedar (*Thuja plicata* Donn). 11 ref. [A.B.I.P.C. 30:5]

Pietrzykowski, J., and Lawniczak, M. "Bitunit," a bitumen-bonded insulation board from wood waste. Przem. drzewny 9, no. 12: 24–8 (1958); Referat. Zhur., Khim. no. 17: 556–7 (1959). [Pol. Abstr. only available]

The floor insulating board "Bitunit" is composed of 80% wood waste (sawdust or shavings) and 20% bitumen having a softening point of 100° C. It has a thickness of 20 mm. and a d. of 600 kg./cu.m. The mfg. process consists of drying the wood at 130° to a moisture content of 10% cooling to 60°, and mixing with the binder. The matl. is then put into molds (2.2 × 1.3 m.) and pressed in hydraulic presses heated to 140° [A.B.I.P.C. 30:7]

4327. Reichman, Everett J. (Simpson Timber Co.) Measurement of compressibility as a factor in evaluating experimental stock furnishes for insulation board manufacture. Tappi 42, no. 11: 908–13 (Nov., 1959).

The consistent math. relationship between dryness of insulation board wet lap and the pressure appl. in its formation can be utilized to predict the operability of a stock furnish on a com. board former. This relationship can be expressed by an equation of the type $y = ab^x$, where y is percent bone dry, a is a const., and b is the pressure appl. to the wet lap during its formation. The values of the expression are pract. indep. of the raw matl. or the degree of pulping refinement. The relationship between dry d. and the pressure appl. to the wet lap also fits the type of math. expression, but the values of a and x are variable depending upon the raw matl. and the pulping trmt. These values can be det. by recording the pressure appl. to lab. test boards, the resulting dryness of the wet lap, and the d. of the test board after drying. The relationships will give linear plots on log-log paper; hence, when the parameters of acceptable wet-lap dryness and desired prod. d. are defined, the lab. results will predict the operability of an exptl. furnish on a com. board former. Caliper of lab. test boards can be effectively controlled by [A.B.I.P.C. 30:7]

Murata, Tokitsu, and Takamura, Norio. The utilization of bark as raw material for fiberboard. I. The influence of bark on qualities of hardboard. J. Japan Wood Research Soc. 5, no. 5: 194–3 (Oct., 1959). [Jap.; Engl. sum.]

The effect of bark addns. on the properties of wet-process hardboard from 8 wood sp. was studied. The woods included red pine (*Pinus densiflora*), cedar (*Cryptomeria japonica*), fir (*Abies firma*), spruce (*Picea excelsa*), beech (*Fagus crenata*), poplar (*Populus maximowiczii*), birch (*Betula maximowicziana*), and linden (*Tilia mandshurica*). Typical bark contents were 12.5% for fur and spruce, 15.4% for birch, and 17.7% for poplar. Mixts. of wood and bark contg. 0, 10, 30, 50, and 100% bark were presteamed for 4 min. and fiberized in a lab. Asplund defibrator for 1 min. under 10 kg./sq. cm. steam pressure. After refining in a Sprout-Waldron lab. refiner, the pulps were sheeted in a 23 by 23 cm. forming box without sizing agent and pressed to *ca.* 1/8 in. thickness at 180° C. Although 70–90% of the bark components remained in the pulp, increasing the bark content of the charge lowered the pulp yields obtained. At the same time, the power requirements for fiberizing and esp. for refining were reduced as the bark content increased; power savings were greater for softwood than for hardwood barks. No difficulties in sheet formation were encountered with mixts. contg. less than 30% bark, except with fir and spruce, which showed a steep rise in freeness with bark addns. above 10%. Except for cedar and linden, pulps of 100% bark fiber could not be pressed, because of dewatering troubles and because of fibers sticking to the caul plate and back screen in the hot press. Increasing the bark content lowered the modulus of rupture in bending, except that of linden hardboard which was not impaired even with 100% bark added, probably because of the strong phloem fibers. With increasing bark content, water repellency was lowered in cedar and fir, but was slightly improved in hardwood boards and greatly improved in red pine hardboards. 5 ref. [A.B.I.P.C. 30:7]

Turn your wood waste into money with a WILLIAMS "No-Nife" HOG

Save money if you burn it

Whether burned for fuel or simple disposal, wood scrap reduced to chips produces more BTU's through complete combustion with virtually no smoke, soot or ash. Scrap in odd lengths and shapes restricts air flow, smothers the fire, requires 3 times the manpower to handle as the same tonnage in chips.

Make money if you sell it

For grinding wood waste to specified size for use in particle board or other products, for wood flour or sawdust, a Williams Hog insures maximum output of a higher quality product while holding labor, operating and maintenance cost to the very minimum.

As part of a COMPLETELY AUTOMATIC SYSTEM to reduce and convey scrap to stoker or burner—or to process, classify and package ground wood—a Williams Hog can turn your wood waste into a highly profitable part of your business.

Write for fact-filled brochure.

WILLIAMS PATENT CRUSHER & PULVERIZER CO.
2714 North 9th Street • St. Louis 6, Mo.

WILLIAMS LINE IS COMPLETE: Grinders • Shredders • Vibrating Screens • Mechanical Air Separators • Heavy Duty Fans • Cyclone Collectors • Complete "Packaged" Plants.

WILLIAMS
CRUSHERS GRINDERS SHREDDERS
OLDEST AND LARGEST MANUFACTURER OF HAMMER MILLS IN THE WORLD

Skrigan, A. I., Shishko, A. M., and Beskin, G. V. Utilization of pinewood stumps and flax fibers for the manufacture of thermal insulation panels. Vestsi Akad. Navuk Belarus. S.S.R., Ser. Fiz.-Tekh. Navuk no. 1: 89–93 (1958); Regerat Zhur., Khim. no. 11: 525 (1959). [Belorus. Abstr. only available]

The addn. of 25%, based on wood wt., of flax fibers to stump wood improves the strength props. and increases the hardness of insulation board. This effect is attributed to the high pentosan content of flax. Joint beating of wood and flax fibers is recommended. The props. of the board correspond to std. requirements (GOST 4598–48). [A.B.I.P.C. 30:7]

Zavadskii, G. V. Wood-particle board of modified composition and its manufacture by a simplified process. Izvest. Vysshykh Ucheb. Zaved., Stroitel. i Arkhitek. no. 4: 137–43 (1958); Referat. Zhur., Khim. no. 11: 525 (1959). [Russ. Abstr. only available]

A 1:1 mixt. of wood shavings and sawdust was soaked in a soln. of calcium hydroxide, then ground in a rod mill. The matl. contg. about 30–40% short (0.5–1.0 mm.) fibrillated fibers and 40–50% coarse particles (5–10 mm. long) was molded into panels having a d. of 250–400 kg./cu.m. and a bending strength of 4–12 kg./sq.cm. The use of sawdust reduces the energy consumption for grinding by 50%. The calcium hydroxide soaking eliminates the need for heat trmt. and, since the matl. contains a considerable quantity of weakly hydrated fibers, the drying time is shortened. The board has props conforming to the requirements of GOST 4598–53, and only simple equipment is needed for its mfr. [A.B.I.P.C. 30:7]

Zombori, János. Laboratory and plant experiments with the joint use of carbamide resins and fillers in the manufacture of wood-particle board. Faipar 8, no. 6: 173–6 (1958); Referat. Zhur., Khim. no. 16: 528 (1959). [Hung. Abstr. only available]

Starch, rye flour, and finely milled sunflower hulls were used as fillers with UF resin adhesive in the exptl. mfr. of wood-particle board having a thickness of 20 mm. and a vol. wt. of 650 kg./cu. m. The board contained 2–8% adhesive, and the adhesive contained 65% of the filler. The fillers used improved the strength and the hygroscopicity of the board. Plant trials showed that, when fillers are used, the rate of UF resin condensation depends both on the temp. and on the quantity of the hardening agent (ammonium chloride). At 20° C. and with 0.05% ammonium chloride, the time of "gelatinization" was 10 hr. A description is given of the technol. process devd. on the basis of exptl. lab. results. [A.B.I.P.C. 30:7]

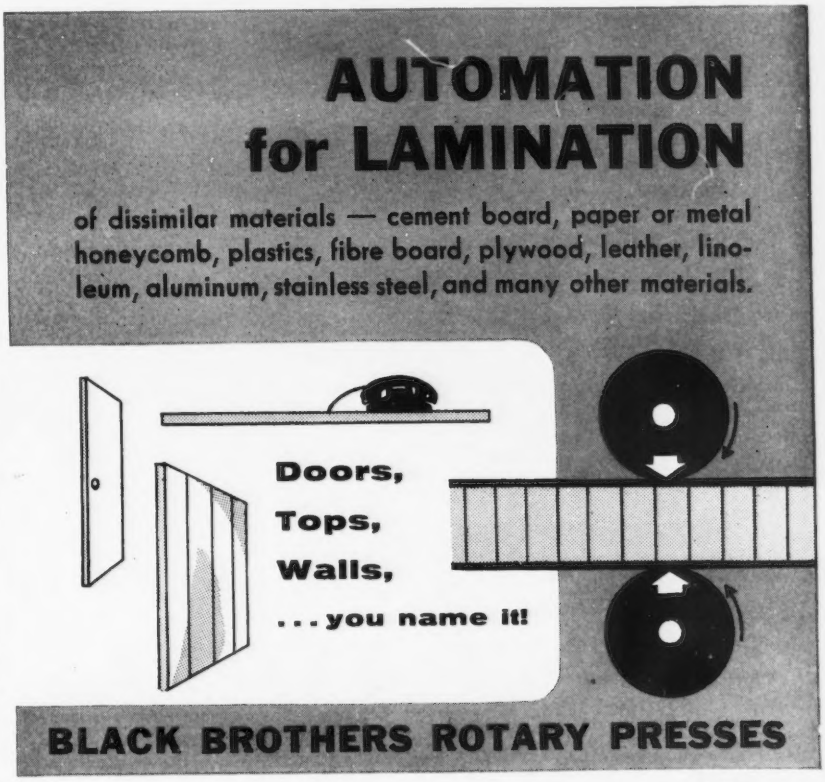
PRESERVATION

Shaltyko, G. E., Pshedetskaya, L. I., and **Sergeenkova, K. K.** The use of sodium thiosulfate in fungicidal wood-impregnating solutions. Zhur. Priklad. Khim. 32, no. 7: 1629–32 (July, 1959). [Russ.]

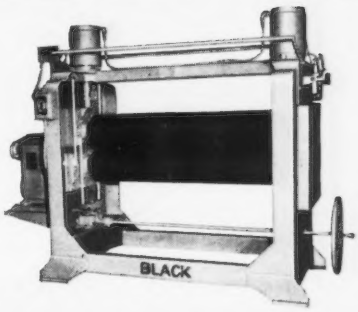
Pinewood samples were impregnated with solns. of sodium thiosulfate of varying concns. (from 0.11 to 1.00 g. equiv./liter) and then trd. with a 3% soln. of copper sulfate. The impregnated samples were leached with water, dried at 100–105°C. to const. wt., and tested for their resistance to the wood-destroying fungus *Coniophora cerebella.* The combined trmt. with sodium thiosulfate (in concns. of 0.6 g. equiv./liter or higher) and copper sulfate imparted complete resistance. At lower thiosulfate concns. the wood was only partially resistant to the fungus. Control samples (impregnated with water and copper sulfate) were fully susceptible. The protective effect of the combined trmt. is attributed to the synergistic action of finely dispersed sulfur and copper sulfide formed in the reaction between copper sulfate and sodium thiosulfate. 11 ref. [A.B.I.P.C. 30: 7]

Liese, W., and Dadswell, H. E. On the influence of compass points on the length of wood fibers and tracheids. Holz Roh- u. Werkstoff 17, no. 11: 421–7 (Nov., 1959). [Ger.; Eng. sum.]

The effect of sunny *vs.* shaded exposure on the length of fibers and tracheids in various growth rings of softwoods, hardwoods, and a bamboo sp. was investigated. The samples, which were collected from fully exposed or slightly shaded trees at various latitudes both north and south of the equator, included the flg. species: *Pinus radiata, Eucalyptus regnans, E. gigantea, Populus robusta, Pseudotsuga taxifolia, Khaya antotheca,* and *Dendrocalamus strictus.* In all samples, consistently shorter fibers were formed on the sunny than on the shaded side of the tree. Differences varied from 0.05 mm. in one hardwood to 0.35 mm. for softwoods. Within a given growth ring, there was a greater difference in the latewood than in the earlywood. Props. such as basic d. and tensile strength of the wood are influenced only slightly by the variable length of fibers from the sunny *vs.* shaded side. Fiber-length detns. appear to be useful in establishing the original orientation (as to compass point) of disk samples cut from a stem. These findings and their significance to the growth physiol. of trees are discussed. 26 ref. [A.B.I.P.C. 30: 7]


AUTOMATION
for LAMINATION
of dissimilar materials — cement board, paper or metal honeycomb, plastics, fibre board, plywood, leather, linoleum, aluminum, stainless steel, and many other materials.
Doors,
Tops,
Walls,
...you name it!
BLACK BROTHERS ROTARY PRESSES

Black Brothers rotary-type laminating presses are ideal for bonding dissimilar plies with pressure sensitive or contact adhesives — more precise, faster, more flexible. 8″ through 134″ capacities. Write for Bulletin 11-C.



BLACK BROTHERS Company, Inc. — Mendota 25, Illinois — Since 1882
Gluing, Clamping, Laminating and Roller Coating Equipment

WORLD-WIDE Forest Products News

Logging in the USSR

A second volume of *Logging Mechanization in the U.S.S.R.*, by A Koroleff, formerly Director, Woodland Research Division, Pulp and Paper Research Institute of Canada, brings up-to-date the author's review of research, development and practice of mechanized timber harvesting in the U.S.S.R.

The author believes that logging in most countries has not received its proper share of the benefits of science and engineering and, generally speaking, is lacking in efficiency. He argues that only in the U.S.S.R. is concentrated research being conducted on logging mechanization, and that only in this country is the ideal system of full-tree logging (i.e. felling, skidding and hauling) being carried out on a commercial, even though small, scale.

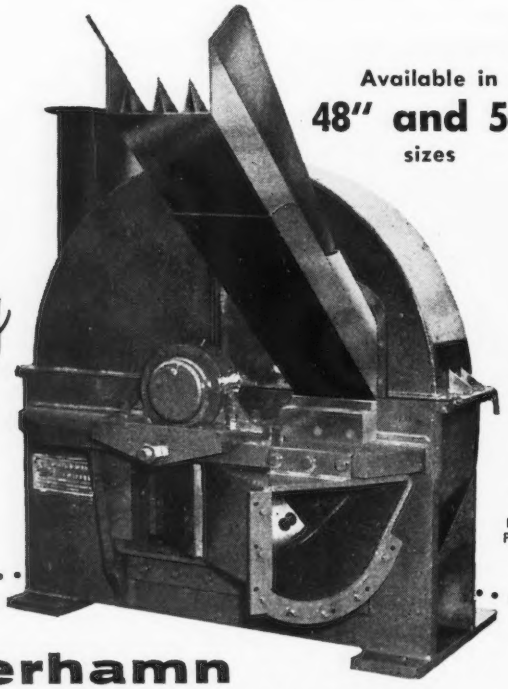
According to the first volume, a fundamental principle of logging in the U.S.S.R. was that forest work should be self-sufficient in power. This was to be accomplished through generation of producer gas from wood for trucks, tractors and logging railways and portable or stationery (mainly producer gas but also steam) electrical stations. However, restrictions on the use of liquid fuel in logging were subsequently relaxed or lifted, and its use has increased. This has affected mainly power saws (used in the forests), truck and tractors.

The second volume emphasizes another important change in U.S.S.R. logging, that is, to remove much of the work to points outside the forest. By changing to full-tree skidding and hauling, the work is concentrated at the more efficient permanent lower landings, where earlier the wood was bucked at expensive temporary upper landings prior to hauling.

The author describing in considerable detail various logging methods, labor efficiency and productivity of the equipment, as well as details of equipment used for cutting, skidding (tractor and cable), hauling including truck, railway and water transport. Similar information is contained in publications of the Joint FAO/ECE Committee on Forest Working Techniques.

—Unasylva, Vol. 13, No. 4, 1959

Introducing the new



Available in 48" and 56" sizes

Patents Pending

Soderhamn
DOUBLE DUTY
HORIZONTAL CHIPPER

Now it's no longer necessary to install a separate re-chipper for salvaging oversize chips, cut-offs and similar valuable "scrap." A new and exclusive re-chipper infeed spout takes care of the job! No extra power supply, labor or maintenance cost — just use the original chipper for the whole job!

The new re-chipper spout is specially designed with deeply grooved bottom which positions waste for feeding correctly to the knife. Re-chipper spouts are available on new equipment, or may be installed economically on existing chippers of any make.

Call, wire, or write for details

SODERHAMN MACHINE MANUFACTURING COMPANY
Talladega, Alabama
West Coast: 9442 S.W. Barbur Blvd., Portland, Oregon

France

La Fumure en Sylviculture (FERTILIZERS IN SILVICULTURE) is a 71-page document put out by the *Société Commerciale des Potasses d' Alsace*. It summarizes the existing literature at present available from all sources on the use of fertilizers in silviculture and the results obtained, distinguishing between the use of fertilizers in the nursery, in plantations, and in natural regeneration, according to the site conditions and the various forest species involved.

No firm conclusions can as yet be drawn but the large number of experiments already carried out seem to show that mineral fertilizers can profitably be used in the forest and to indicate the desirable dosages according to the soil and tree species. For instance, Japanese larch has a low requirement for potash but Douglas fir has a high requirement and reacts strongly to treatment.

—Unasylva, Vol. 13, No. 4, 1959

Mattison

Ripsaws

and

Moulders

SET PROFITABLE PRODUCTION PACE at

Myrtle Desk Company

High Point, North Carolina

People like Mattison woodworking machines for many reasons—quality work, reliable operation, and high rate of production—all factors that affect profits!

Myrtle Desk Company says: "We have six Mattison 202 ripsaws cutting various types of lumber from soft woods to very hard woods, and have had no trouble at all in cutting straight glue joints on such material as hard white maple and Louisiana pecan lumber. They operate at high speeds and do very fine work. We are extremely well pleased with them.

"We are now operating two Mattison No. 276 moulders, primarily with carbide knives at very high speeds. We are cutting maple and pecan, along with regular furniture woods of walnut and oak. These machines have been running for several years and have given us excellent service.

"We are pleased to recommend these two machines to prospective users."

If you want profitable production at today's reduced volume—plant efficiency paced by precision machines designed to produce top quality at highest speeds—see the Mattison ripsaws and moulders work. Your Mattison dealer can arrange a demonstration at the factory or in a "Mattison-equipped" plant near you.

MATTISON

WOODWORKING MACHINERY

MATTISON MACHINE WORKS ROCKFORD, ILL. U.S.A.

"Built better . . . to produce better quality"

Mattison Machine Works
545 Blackhawk Park Ave.
Rockford, Illinois

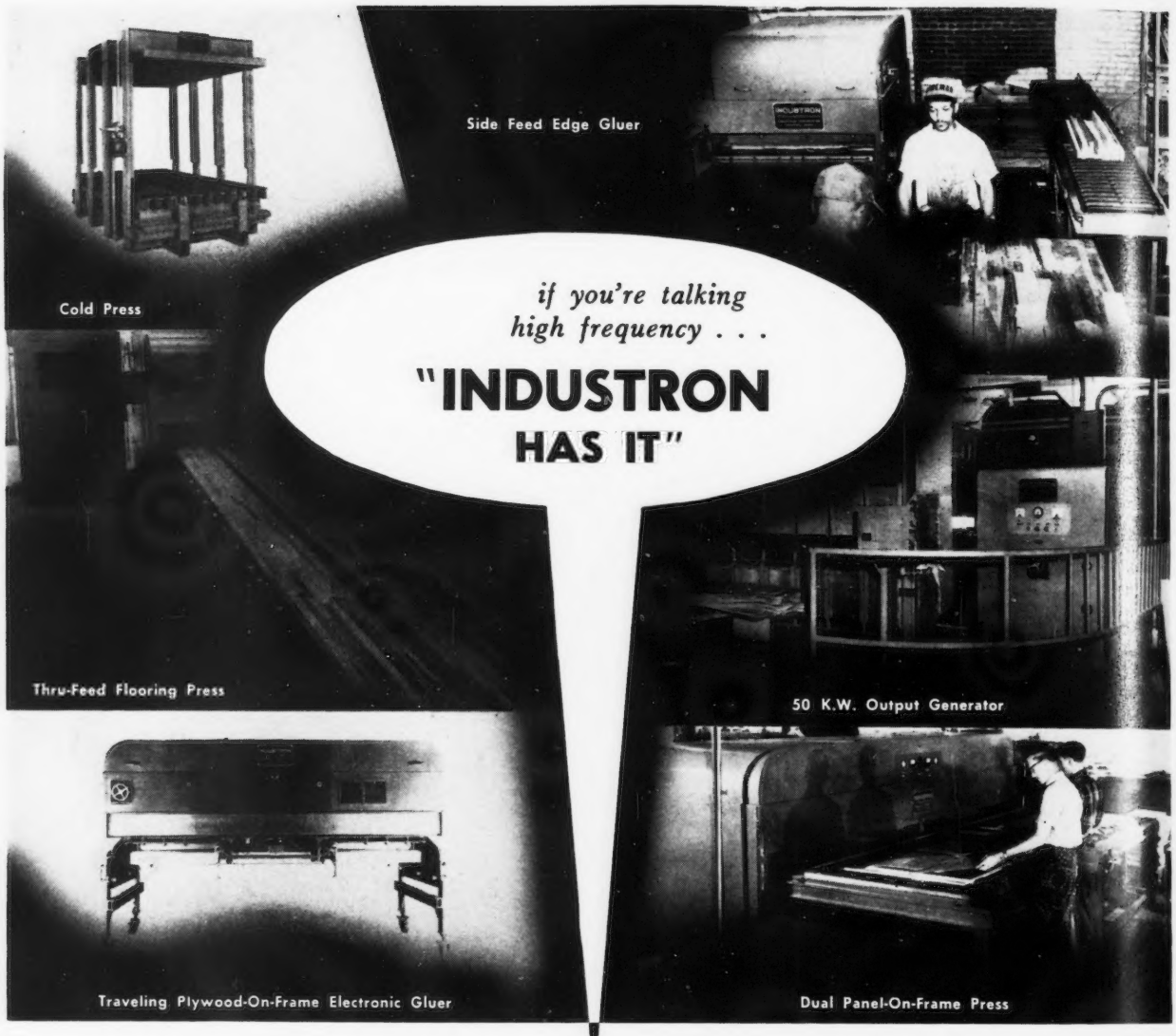
Gentlemen: Please send literature describing your Model 202 ripsaws ☐; No. 276 electric moulders ☐.

Name_____

Firm_____

Address_____

City_____ Zone_____ State_____



if you're talking high frequency . . .

"INDUSTRON HAS IT"

HIGH FREQUENCY SPECIALISTS to the WOODWORKING INDUSTRY

Industron manufactures a complete range of standard model edge gluers, lumber laminators, cold presses and high frequency generators.

Industron's standard line of electronic gluing machines includes the following: • One man operated side feed Model E edge gluers • High production Model IF thru feed edge gluers • Panel on frame presses and generators • Glue spreaders of the conveyor type for resin glues.

High frequency generators for serpentine and assembly work, ranging in size from 1 to 100 K.W. output • Lumber banding presses for lumber or particle board panels • Particle board edge gluing equipment • Plastic laminating presses — air operated.

In addition to the above standard line, Industron manufactures all types of special high frequency equipment for the woodworking industry.

CERTAIN SALES TERRITORIES AVAILABLE . . . CONTACT

INDUSTRON CORPORATION

WRITE FOR COMPLETE INFORMATION AND BROCHURE

55 NEEDHAM STREET, NEWTON HIGHLANDS, MASS. DEcatur 2-1477